Design of return assist mechanism and reduction of dual clutch pedal effort

A thesis submitted in partial fulfillment of the requirement for the award of the degree of

Master of Engineering

in

CAD/CAM Engineering

Submitted by

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CERTIFICATION

This is to certify that the work down in this thesis report title **"Design of return assist mechanism and reduction of dual clutch pedal effort"** submitted in partial fulfillment of requirement for the award of Master of Engineering Degree in CAD/CAM Engineering in the Mechanical Engineering Department of Thapar Institute of Engineering & Technology, is an authentic record of work carried out by me under the guidance of Dr. Devender Kumar, Assistant Professor, Mechanical Engineering department, Thapar Institute of Engineering & Technology, Patiala, and Mr. Digendra Singh, Senior Manager, Escorts Ltd. Corporate KMC, Faridabad. The matter embodied in this report has not been submitted in any part or full to any other university or institute for the award of any degree.

30/07/2018

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This is to certify that above declaration made by the student concerned is correct to the best of my knowledge & belief.

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Lastly, I would also like to thank my parents for their years of love and encouragement. They have always wanted the best for me and I admire their determination and sacrifice.

Mahipal

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Abstract

Improved design for high performance machinery has always been the requirement of automotive as well as applied industries. Interaction of machines/mechanism with its user and easiness in operation is a very important field of study for better customer satisfaction. Present study involves a long term customer demand to decrease the effort applied on clutch pedal to actuate the bulky single plate dry friction clutch. long hours of continuous usage of agri machinery during seasonal crop cultivation, put lot of fatigue on drivers muscles, which same time lead to permanent disability in the body parts of drivers over few years. Present work addresses this practical issue and tried to eliminate the tedious task of pure mechanical linkage for engagement & disengagement of clutch pedal. The process of optimization includes various design, starting from linkage redesign to addition of motor or solenoid actuator to make the task simpler and effective. In the final stage the design mechanism with 'V' shape and 4 bar mechanism linkages and solenoid actuator comes out to be the best among all the designs involved in the present study.

Nomenclature

Acronyms

CAD	Computer aided design
ADAMS	Automated Dynamic Analysis of Mechanical Systems
MSC	MacNeal Schwendler Corporation
VPD	Virtual Prototype Development
DOE	Design of Experiments
HDV	Heavy duty vehicles
FEM	Finite element method
VSA	Variation Simulation Analysis
ECM	Electronic Clutch Management
SQ	Sound Quality
CAE	Computer aided engineering
FEA	Finite element analysis
CFD	Computational fluidic dynamic
ACM	Area contact method
NVH	Noise, vibration, and harshness
FEAD	Front end accessory drive
MOD	Multi-disciplinary optimization
HIL	Hardware in loop
ECU	Electronic Control Unit

CHAPTER- 1

Introduction

1. Clutch

The clutch is the flexible coupling to transfer engine power to the transmission.

1.1 Clutch disc

The clutch disc is splined to the input shaft of the transmission. The disc itself rests between the flywheel and the pressure plate, both of which rotate with the engine. So the clutch disc is spinning with the transmission, and on either side of it is a metal surface which rotates with the engine.

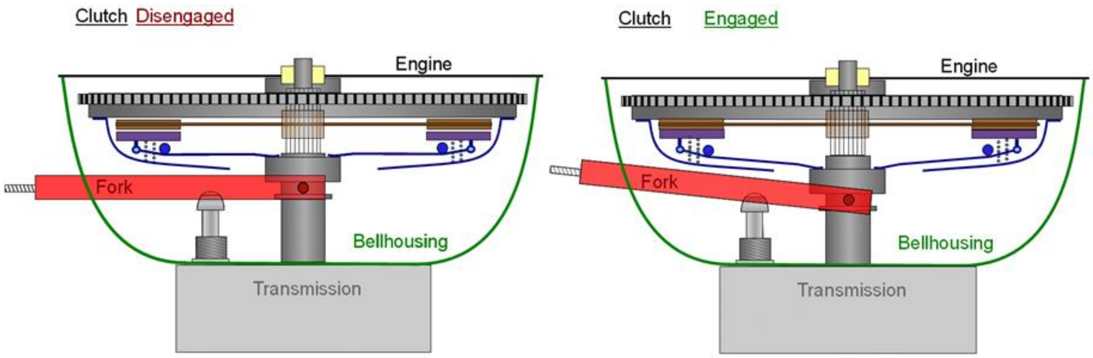

Fig. 1.1 Clutch engage/disengage mechanism

1.1.1 Dual clutch transmission

- Used two separate clutch plates
- PTO shaft

Fig. 1.2 Dual clutch model [1]

A clutch is an essential part of the drive train components used to transfer torque in different types of machinery. These days, designs of vehicles are largely affected by the need of better comfort of driver. Pedal design is important aspect related to the driving comfort. High clutch pedal effort is a frequent customer complaint as this leads to high fatigue of operator and lesser productivity. Most of the drivers are generally facing problems with knee pain due to high pedal effort. Now day's latest technologies like turbocharging, wet clutch etc. are incorporated in the drivetrain system which increases engine power but it will also increase the clamping load of the clutch. Increase in clamping load of the clutch tends to increase in clutch pedal effort.

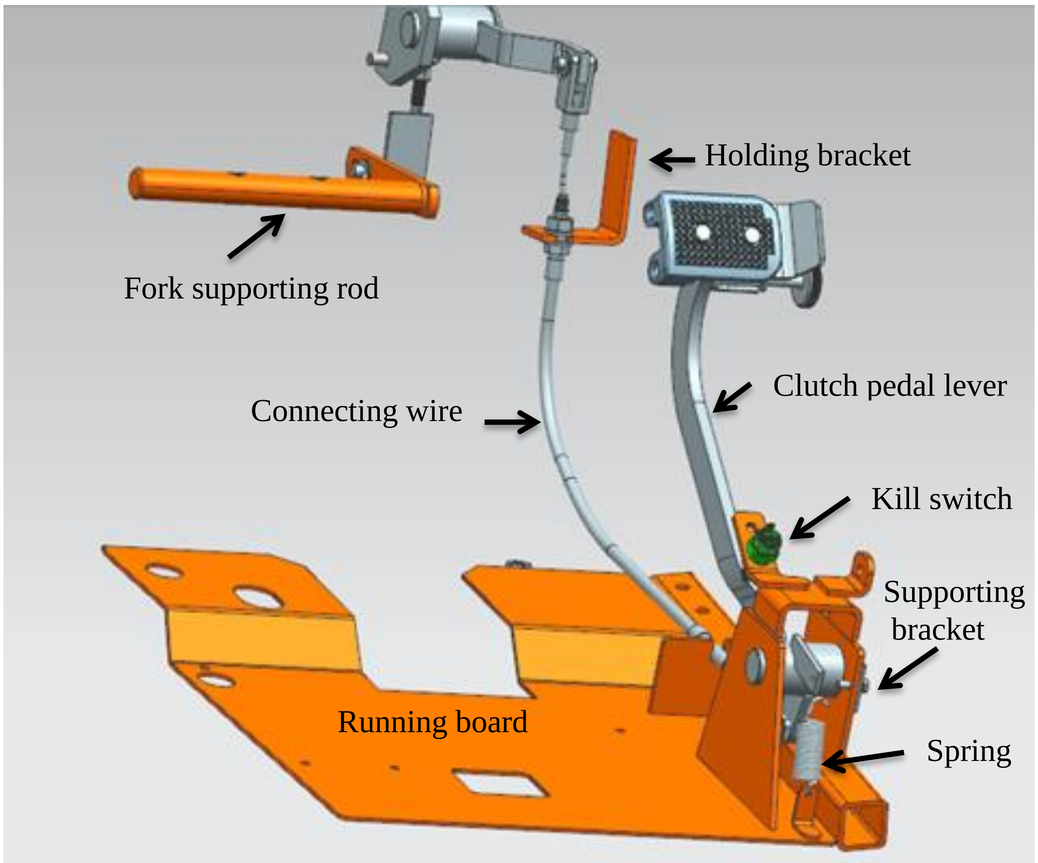

Fig.1.3 CAD Model of Clutch pedal mechanism [1]

Increasing engine power and customer requirements for light clutch, put lot of design challenge on the designers to make it easy in operation and minimum cost of production. In the past various materials have been used like asbestos for disc friction clutch. Typically, an organic resin with copper wire facing or a ceramic material is used in modern day clutches. Generally in heavy applications like racing and heavyweight hauling shipping, ceramic material are used, though the tougher ceramic material adds into the plate wear of flywheel and pressure plate wear. In "wet" clutches composites paper material are very common. Since in the case of "wet" clutches an oil bath or flow-through cooling method is used so that the disk paper stays lubricated that is why very less amount of wear is observed while using composite paper material is shown in fig. 1.1.

1.1.2 Assembly of a clutch linkage mechanism

All the part are introduced with working processes the assemble model of clutch linkage mechanism is shown in fig. 1.2

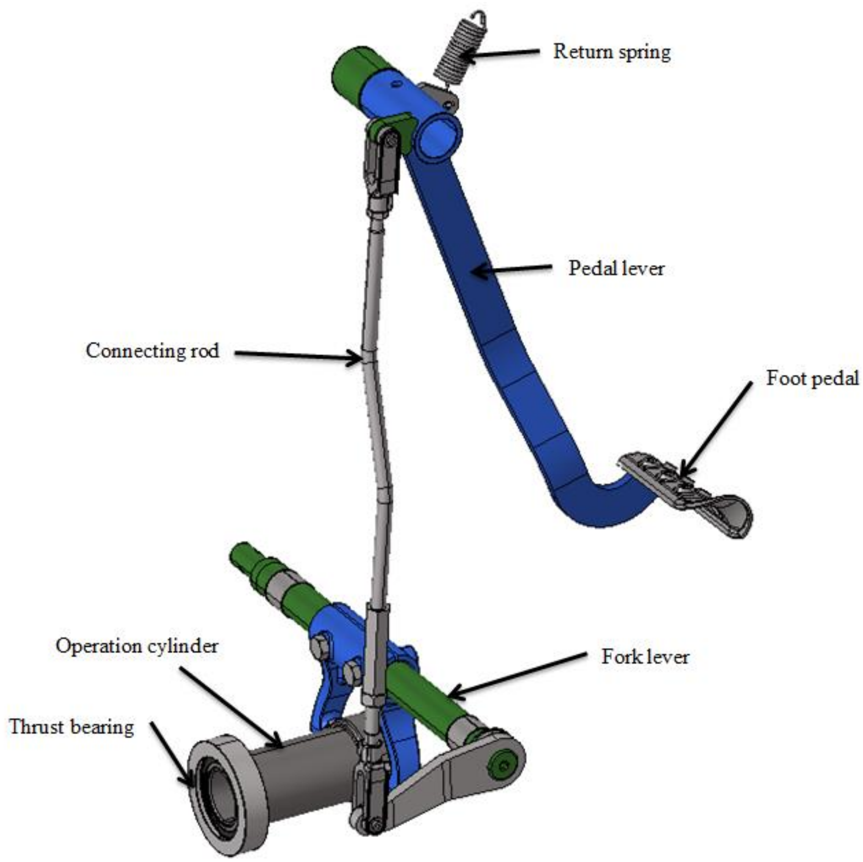

Fig. 1.4 Assembly of a clutch linkage mechanism [1]

1.2 Link assembly parts of clutch release fork with clutch pedal

1.2.1 Clutch release pedal

1.2.2 Return spring

1.2.3 Connecting rod

1.2.4 Clutch release fork

1.2.1 Clutch release pedal

A pedal or lever is a part of clutch linkage assembly, it is used to engage or disengages driving mechanism and when the driver presses the pedal manually or using mechanism like hydraulic pressure then clutch is disengaged, otherwise it remains engaged due to spring forces. Clutch pedal design depends on need and type of vehicle being used. The position of the pedal also depends on vehicle requirement. The CAD model of pedal show in fig. no.1.3

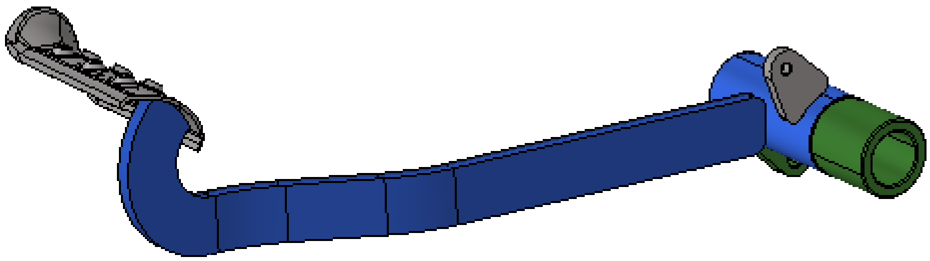

Fig. 1.5 CAD model of clutch pedal

1.2.2 Return spring

Closed coil helical spring is used to retract the pedal to its rest position as shown in fig. 1.4.
Torque is absorbed by the pressure plate which is rotating in relation with the clutch disc. This engagement reduces the shock produced during engagement.

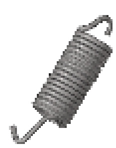

Fig. 1.6 CAD model of closed coil helical spring

Torsion spring works in twisting of coil which resists its motion while storing enery. Later on this stored energy is used to actuate the spring.

1.2.3 Connecting rod

In clutch linkage mechanism, connecting rod is used to connect the clutch pedal with clutch release fork. The connecting rod transfers the motion from pedal to clutch release fork. After that the clutch will be engaged or disengaged. The CAD model of connecting rod show in fig. 1.5

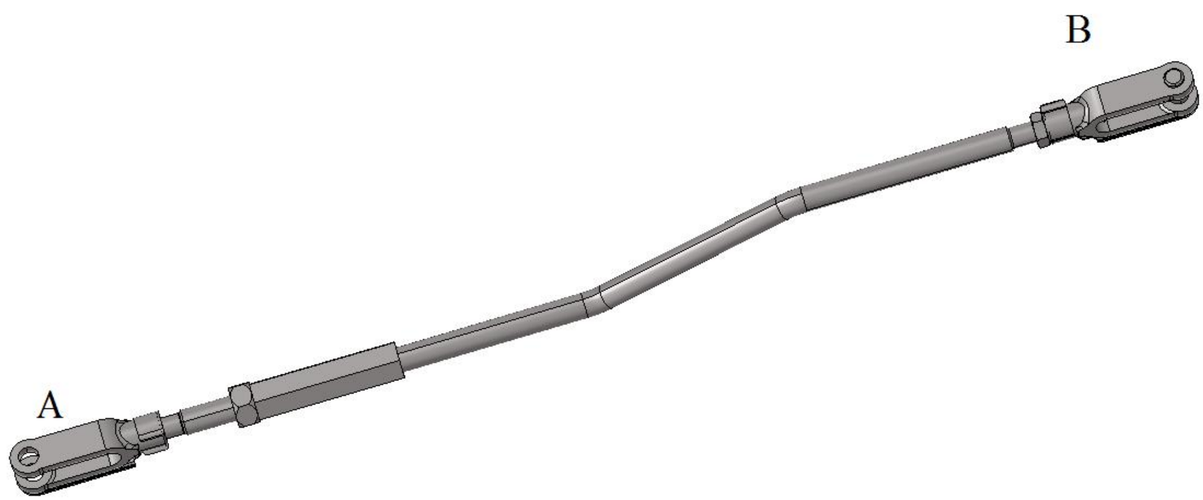

Fig. 1.7 CAD model of clutch pedal connecting rod

Side ‘A’ of connecting rod is connected with clutch release fork and side ‘B’ of connecting rod is connected with clutch pedal. When foot pedal presses the connecting rod, it transfers the motion to clutch release fork and then clutch disengages. Side ‘A’ is connect with clutch release fork and provides the motion of clutch release fork. In tractor clutch linkage mechanism system mostly using metal rod but in car or other vehicle uses connecting cable to engages or disengages the drive mechanism. The advantage of the metal clutch pedal connecting rod that, it is more durable as compare to connecting cable. The advantage of connecting cable mechanism is, it is cheaper as compare to metal rod. The connecting cable mechanism is more flexible then metal rod.

1.2.4 Clutch release fork

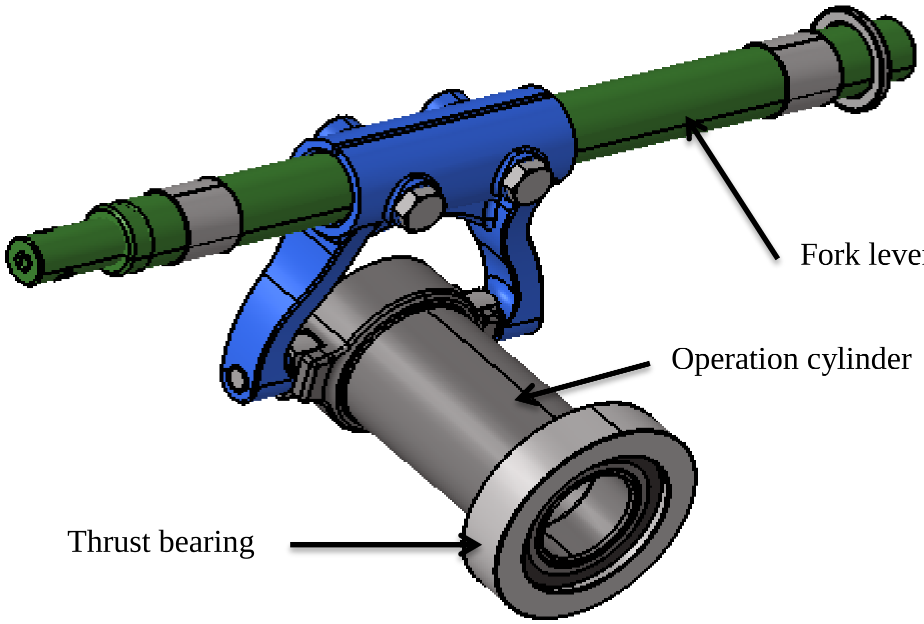

Fig. 1.8 CAD model of clutch release fork

When grasp pedal is pushed the toss out bearing exchanges to the flywheel, pushing in the weight plate's discharge fingers and moving the weight plate fingers or levers against weight plate spring power. This activity moves the weight plate far from the grasp circle, hence interfering with control stream. The grasp fork and interfacing linkage change over the development of the grip pedal to the forward and backward development of the grasp tosses out bearing. To separate the grip, the discharge bearing is advanced toward the flywheel by the grasp fork. As the bearing contacts the weight plate's discharge fingers, it starts to turn with the weight plate get together. The discharge bearing keeps on pushing ahead and weight on the discharge levers or fingers causes the power of the weight plate's spring to move far from the grasp circle. To draw in the grasp, the grip pedal is discharged and the discharge bearing moves from the weight plate. This activity permits the weight plate's springs to drive against the grasp circle, drawing in the grip to the flywheel. Once the grasp is completely connected with, the discharge bearing is typically stationary and does not pivot with the weight plate. On a run of the mill establishment, one end of the link is associated with the grasp pedal and a spring is joined to the pedal gathering to keep the pedal in the "up" position. The opposite end of the link is associated with the grip discharge fork with a fitting that takes into consideration free-play changes. At the point when the grip pedal is discouraged, the link pulls the grasp fork, causing the discharge bearing to advance against the weight plate.

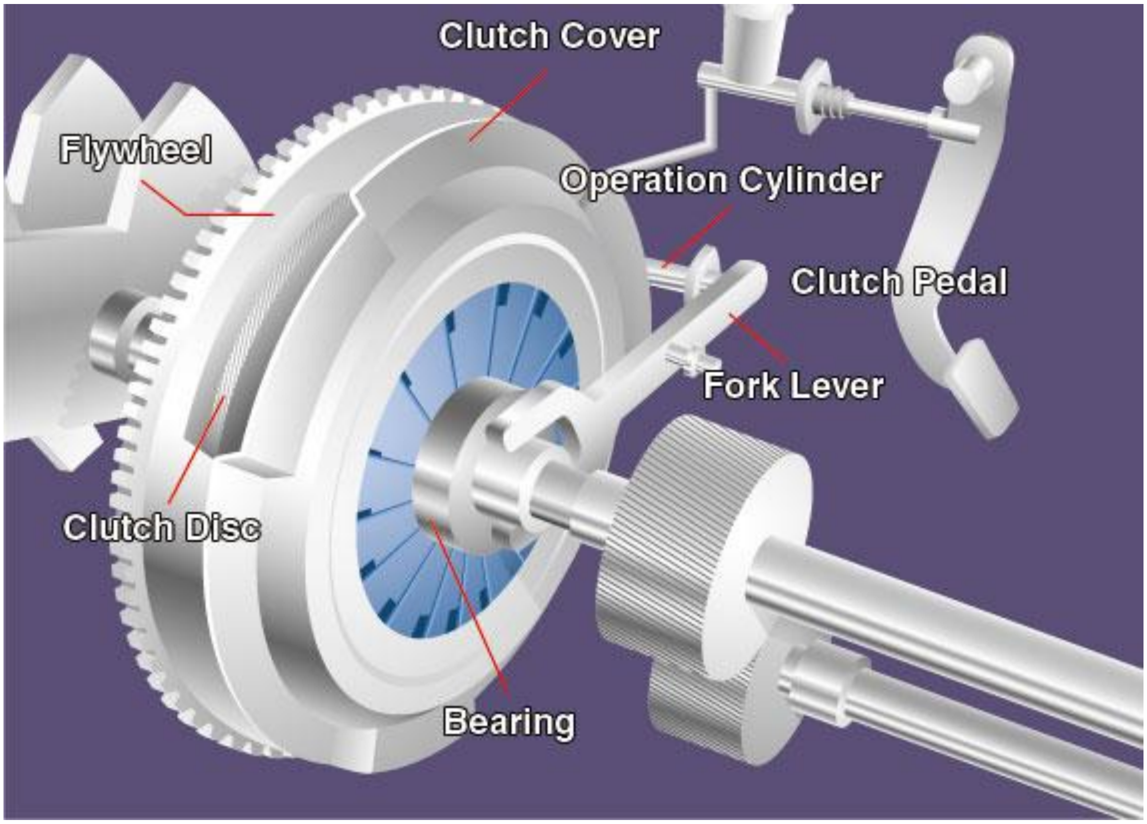

Fig. 1.9 Clutch release fork mechanism [2]

At the point when the grip pedal is squeezed, a link pushes on the discharge fork, which presses the toss out bearing against the center of the stomach spring. With the spring pushed, the grasp circle is then detached from the pivoting flywheel that is appended to the motor. At the point when the pedal is discharged, the plate will connect with contact with the flywheel and transmit the torque from the motor to whatever remains of the drive prepare.

1.3 Introduction to ADAMS software:-

ADAMS is an Automated Dynamic Analysis of Mechanical Systems is a multibody dynamics simulation software equipped with FORTRAN and C++ numerical solvers. ADAMS was originally developed by mechanical dynamics incorporation, which then was acquired by MSC (MacNeal Schwendler Corporation) Software Corporation. ADAMS has been proved as very essential to Virtual Prototype Development (VPD) through reducing product time to market and product development costs.

1.4. Base modules

1.4.1 ADAMS/View

1.4.2 ADAMS/Solver

1.4.3 ADAMS/Postprocessor

1.4.1 Extended simulations

- Several additional modules sold separately are also available for extended functionality. Vibration analysis through ADAMS/vibration includes mode shape analysis.
- SISO and MIMO closed loop control system modeling and simulation is available through ADAMS /controls.
- It can simulate flexible links, via ADAMS/view flex and/or ADAMS/flex. Its approach to flexible body modeling is that of modal analysis which uses a modal neutral file.
- ADAMS/insight can be used to study Design of Experiments (DOE) and to optimize a design.
- ADAMS /SDK (software developer's kit) can be used for building customized modules. Some native customizations hitting special industry problems are ADAMS /car, ADAMS /engine, ADAMS /aircraft, ADAMS machinery; all of which template based customized stand alones of ADAMS /view.
- ADAMS /tire simulate complex non-linear behavior of car tires, using experimental models. Product lifetime reduction under dynamic and fatigue loads is studied by ADAMS /durability.

1.5 Introduction to finite element analysis

Finite - It reduces degrees of freedom from infinite to finite with the help of discretization i.e. meshing

Element - All the calculations are made at limited number of points known as “nodes”. Entity joining nodes and forming a specific shape such as quadrilateral or triangular etc. is known as “element”.

Analysis - Finite element analysis belongs to numerical method category.

- Mathematical approach
- Based upon discretization
- Approximate results

1.5.1 Procedure for finite element analysis

Pre-processor

- Geometry formulation
- Definition of type of analysis
- Material properties
- Element type
- Discretization
- Loads and boundary conditions
- Model display

Solution- Run analysis to obtain solution (e.g. Stresses & displacements)

Post processing- Graphical display of results for quick and easy interpretation of results.

1.5.2 Advantage of finite element analysis

The advantages of FEA are as follows:

- Visualization (increases)
- Design Cycle time (decreases)
- No. of prototypes (decreases)
- Testing (decreases)
- Optimum design

1.6 Methodology of design and analysis

It is very difficult to solve the pedal load problems when clutch transfers high torques as it does in HDVs. A design optimization is required depending on clutch energy and clutch pedal effort. Clutch energy affects the vehicle performance which is one of the most critical parameters. On the other hand, the clutch pedal effort is critical for both clutch system performance and ergonomic conditions which effects customer satisfaction.

Methodology of present work involves structure of modal design, analysis and optimization of clutch actuation system. In this work 4 models are analyses and optimized to make better actuation for clutch release fork. As shown in fig. 1.8 in first method use a motor for actuating the clutch release fork. In design 2, a solenoid actuator is proposed which is used to make the clutch engagement more effective and quick. But this model not satisfied the requirement of efforts to clutch release fork. In order to decrease the pedal effort, there is need to optimize the design of linkages which connect the pedal and the actuating mechanism. Design 2, 3 and 4 analysis three different design of linkage mechanism to reduce the pedal effort as well as solenoid effort.

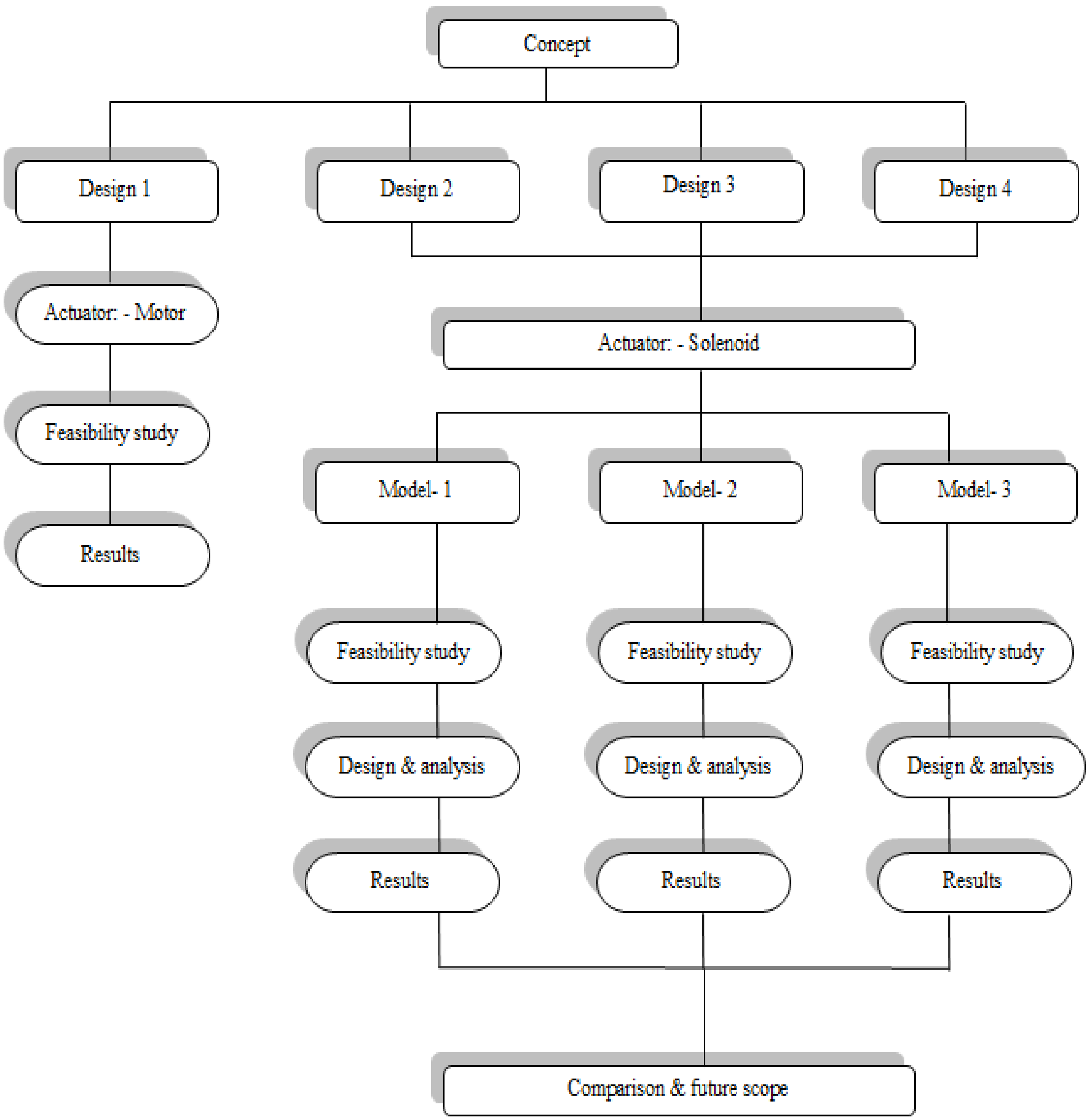

Fig. 1.10 Design and analysis methodology

CHAPTER- 2

Literature review

Presently multi day, International tractor producing industry centers on the arrangement investigation amongst crankshaft and information shaft for clutch frameworks. The effects of component design and tolerance on pivotal arrangement estimations with respect to these applications are talked about. The study demonstrates that resistance d of mixes with Variation Simulation Analysis (VSA) encourages operational permeability; enhances quality, decrease fabricating cost, and empower diminishment of generation discharge time [3].

Specialist likewise chipped away at clutch pedal section to make actuation more effective and lessen the pedal exertion. This paper [4] centers around decreasing the clutch pedal exertion (load) without changing the clutch discharge stack or pressure driven and mechanical proportions. This will be accomplished by joining a leaf spring and a cam and roller system in the clutch pedal itself. The instrument gives the support to the driver amid separation of clutch and furthermore guarantee great pedal return-capacity while commitment. There are systems coordinated inside the clutch pedal to decrease the heap like Over-focus spring, twofold torsion spring, and Servo support and so on.

In this work initial a torsion loop spring was mounted between the lever and bolster section to work culminate clutch pedal.

The strong powers created amid a clutch pedal task were dissected. Fifteen subjects participated in the analysis. Four plan parameters (situate tallness, pedal travel, pedal travel tendency, pedal obstruction) were controlled and twenty eight setups were tried. For every preliminary, the subjects were requested to rate the apparent inconvenience. Individual solid powers of the left leg for every preliminary were reenacted utilizing movement recreation, reverse progression and static streamlining. The examination of these recreated solid powers gave an understanding into the way a clutch pedal task is performed as far as strong effort and coordination.

Similitudes in solid power examples of various subjects were discovered [5]. The way an adjustment in origination parameters of an auto inside influenced this solid effort was likewise researched. This last point uncovered that some origination parameters affected solid powers fundamentally. The connections between strong pressure and subjective distress were additionally considered.

In any case, no strong foundations were discovered that could clarify the subjects' discomforts evaluations.

Levi Silva worked on clutch release bearing and sliding tube on the clutch pedal hysteresis [6]. Work additionally includes, influencing model of the logical model and advancing the clutch to pedal exertion. Connection between subjective reactions of human comfort and the greatest power accomplished amid the finish of-travel affect and the normal slant of the power uprooting bend amid the underlying withdrawal stage is troublesome. At the point when end clients clutch about clutch pedal activation comfort, auto business people and automakers change the whole clutch framework, including weight plate, clutch circle and clutch discharge bearing (CRB) to take care of the issue and the suspicious underlying driver lies on the CRB. By and large, past examinations indicated bearing was useful yet solid sullying was inside the ringer lodging, on the clutch and between the CRB with plastic lodging and the sliding tube. Tests to think about the impacts of sullying under high temperature, speed and the utilization of oil on the plastic lodging made of PA66 material on the rubbing surfaces and wear were additionally considered. Clutch discharge heading mounted with PA66 lodging rubbing against steel tubes were tried. Martini, J. what's more, Armstrong, T. taken studied and worked on magnesium die casting clutch and brake pedal support bracket, created segments in aluminum or framed steel and afterward changed over to magnesium with no basic changes [7].

This procedure does not do justice to the numerous points of interest which magnesium can offer. Today, engineer are planning to use the properties of high purity die cast magnesium and outlining car auxiliary bracket section with every one of the benefits of light weight, thin dividers, high quality, and intricate shapes taking out numerous segments and supplanting them with one die casting

A case of this procedure is the W-auto clutch and brake pedal support section. Scientists are additionally working the lessening techniques for clutch pedal vibration and drive prepare rattling clamor from clutch framework [8]. The clutch pedal vibration and inside clamor are for the most part influenced by the dynamic attributes of the clutch cover assembly.

Specialists accomplished a high connection between vehicle test information and results utilizing this technique while energizing clutch framework as well as the motor framework. Analysts have built up an excitation technique to assess the dynamic qualities of the clutch cover get together. Japanese researchers dealt with clutch lever configuration issues clutch having levers are predominant in the North American market of medium and substantial trucks. The motivation behind this paper was to explore dynamic and kinematic issues identified with clutch levers [9].

Clutch designers were basically concerned with the impacts of levers on clamp load in condition of the clutch engaged, yet neglect or downplay consequences of dynamic effects on the discharge properties of clutches. Lever ratio fluctuates both amid the bearing flight and with wear of the clutch. The lever proportion variety influences both the lift of the weight plate and the clutch cinch stack. The reenactment model can be used to enhance both lever shape and lever situating amid the whole clutch life.

Avoidances of levers and other inside activation segments influence the weight plate lift as well as commitment nature of the clutch. Diffusive powers following up on levers influence the cinch stack, discharge load and steadiness of lever area amid clutch activity. Inertia forces of levers can influence the strap function and increment or abatement the clutch lift. Changes in dependability of lever situating amid release can limit clutch hysteresis [10]. Clutch performance improvements were made possible by simple design changes of levers.

The primary goal of these exploration kinematic and dynamic issues influencing the interior activation procedure of the clutch and, along these lines, to infer scientific models of clutch lever function amid actuation. A definitive objective was to incorporate these models into clutch configuration rehearse with a specific end goal to enhance imperative clutch qualities.

In India the majority of tractor producing organization taking a shot at clutch pedal power diminishing and enhance the clutch exertion and increment the proficiency of double clutch. Escorts restricted are chipping away at the clutch improving and lessen the pedal load. An Escort Ltd. is in process to enhance the clutch pedal travel separation and angle of comfort.

The Indian researchers are presently working on models to study the clutch pedal exertion [11]. Utilizing idea of Electronic Clutch Management (ECM) by actualizing a keen mechatronic clutch actuator with particular, coordinated sensors straightforwardly inside the actuator. This improvement readies the ground for another time that eliminates to the clutch pedal and accomplishes the objective of utilizing a 2-pedal framework.

Analysts have likewise built up a few models to think about the impact of clutch framework parameters on clutch pedal execution in an exploratory plan. The most basic elements were choice of discharge stack on discharge bearing, mechanical proportion, clutch servo support pneumatic force, pressure driven proportion, extension misfortune proportion, and spring force.

The consequences of the examination demonstrates that clutch servo support pneumatic stress has the most huge impact on the pedal exertion, and the level chose in the test configuration is a vital parameter for the dependable outcomes.

Some work was accounted for on sound quality assessment of a brake and clutch pedal get together [12]. Sound Quality (SQ) of brake and clutch pedal get together assumes a vital part in adding to vehicle inside commotion and view of sound. Calm activity of brake and clutch units additionally mirrors the vehicles manufactured and material quality. Clamor discharged from these sub-gatherings needs to meet certain acknowledgment criteria according to various OEM prerequisites. Very little work has been carried on this throughout the years to describe and measure the same. An attempt has been made in this paper to contemplate the sound nature of brake and clutch pedal congregations at segment level and approve the same by recognizing the parameters influencing SQ. Impact on clamor at various natural conditions was considered with common [13] working cycles in a hemi-anechoic cylinder. The impact of sensor switches incorporated inside the clutch and brake pedal on sound quality is broke down. It is discovered that the working qualities of switches Drives the commotion and SQ. Wavelet investigation was completed to associate clamor sound quality metric with time-recurrence adequacy adjustments. Jury assessment was performed to connect subjective to target information. Basic changes were then recommended to enhance the view of sound. Critical change in the brake and clutch pedal get together solid quality was accomplished in item improvement with negligible effect on cost.

In this time car industry has turned out to be extremely worry about lessening item fabricating time and increment nature of item [14] this need made car industry decrease the quantity of models and answer more on Computer Aided Engineering (CAE) for estimating and last plan of item. Research depicted streamlined and mechanized system to anticipate solidness utilizing CAE techniques. This approach is utilized to get to solidness of item structure. This strategy depends on the idea of modular strain vitality and is checked by contrasting expository outcomes and field disappointment information. Along these lines CAE can demonstrate powerful device to decrease time and cost in plan and item advancement of car segments. With the expanding need quicker item improvement but then accomplish the ideal outline, push on precise FEA of parts and system is felt [15]. The three crease reason for this paper is to set up an exact FE demonstrating method and examination system that reproduces the test conditions, supports in precise weariness life forecast and above all, gives a basic technique to virtual approval of interfacing bar. In this paper the pivotal loads have been considered for assessment of exhaustion life of associating bar. The gas and latency loads are ascertained for a given engine speed, crank diameter, connecting rod length, connecting rod mass, piston diameter, peak firing pressure for maximum torque.

The ratio of compressive load to tensile load should be calculated before the FEA is conducted. This would help in determining the bending stresses caused by inertial loads. Cylinder head and crankcase assessment through CAE and CFD in the beginning period of configuration gives noteworthy jump in streamlining and approving these segments. The investigation gives multifold benefits [16] Identifying thermo-auxiliary problem areas in view of stream conduct inside the water jackets and Prediction of gasket fixing weights for evaluation of the motor head-crankcase joint integrity. Simulation and analysis with the help of finite element full vehicle show are a key piece of the vehicle improvement. This has been totally incorporated in the design and advancement cycle [17].

The midsize sized SUV BIW structure is decided for the improvement. FEA model is created utilizing shell components to show the BIW panels. Rigid beams and Area Contact Method 2 (ACM2) connector components are utilized to display the seam and spot welding individually. The design should likewise meet the stiffness and strength targets. This is assessed independently and focuses for solidness and quality are met with adjustments as far as little nearby fortifications as required. DOE is utilized to check the stiffness of the boards. This information is investigated and in light of the consequences of the results, panels are chosen for mass decrease. Design of a panel board retainer for ideal framework execution attributes, for example, NVH (noise, vibration, and harshness) and part strength amid crash. These strategies with FEA procedures work together with information procurement of part and frameworks test to give a closed loop investigation to test relationship of execution [18] Upon verification of the instrument panel system model for a particular performance property, alternatives to enhance the system properties or lessen the cost might be evaluated analytically, supplanting the verifiable "cut and test" technique. Besides, the assembling procedure definition for the retainer is produced simultaneous with the plastic design part. Analysis of manufactured part are utilized to decide material flow, part cooling, part shrinkage, and at last, retainer fit and finishing. Potential design changes are audited analytically to decide impacts with respect to the injection molding process; refinements to process are then decided for ideal plastic part integrity and dimensional quality. With the expanding interest for light weight motors, the design of FEAD (Front end accessory drive) Brackets has step by step moved from traditionalist cast iron configuration to enhanced aluminum. Subsequently there is a necessity for a virtual approval technique that is robust and exact[19]. The paper depicts a virtual approval technique embraced for FEAD sections that gives exact stress value and in this way guarantees precision in anticipated weariness factor of safety for design. The reproduced dynamic stresses are later contrasted with the test outcomes and a decent connection is observed. The testing system used is a type of accelerated testing intended to delineate the life cycle with this present reality utilization profile. This paper goes for illustrating a deliberate approach for design of crankcase for fatigue which would eliminate design iterations for durability [20] this permits a bigger extension for design change at the concept level as the design particulars are not developed at this stage. A procedure of stress optimization is adopted which gives exact dimensional input to design variable. The approach is outlined with a case study where a current crankcase was enhanced for weariness and huge weight reduction was accomplished. In current competition car industry is under substantial strain to diminish time to market. First time right design is an imperative angle to accomplish the time and cost targets [21]. CAE is a tool which causes designer to think of first time right model. This additionally calls for high level of trust in CAE simulation results which must be accomplished by correlation activities. In cars a large portion of the structures are subjected to vibration from dynamic loads. All the dynamic road loads are irregular in nature and can be effortlessly expressed in terms of power density functions. In the present situation basic structural durability of the parts subjected to vibration is done partially through modular performance and somewhat through frequency response analysis. The paper portrays an orderly and economic methodology of mapping all the accelerated tests in a solitary PSD and further utilizing it for vibration fatigue. Likewise a decent correlation of simulation comes about with the test data is displayed for the PSD based approach. Virtual validity is one of the essential stages for any new product development. The underlying advance for virtual approval for durability analysis of vehicle is to comprehend the loads which are transmitted to body from the roads. In current technique standard 3g stack cases are considered. These are most noticeably worst load cases which indicate more number of high stress areas on vehicle. In actual vehicle running condition, dynamic loads are applied on vehicle structure. [22] These dynamic loads can be acquired by estimating the loads going ahead the vehicle through road data obtaining system.

The utilization of estimated loads pose challenges due to the non-accessibility of delegate mule in the underlying period of vehicle advancement. To overcome this, Mahindra and Mahindra built up another approach which empowered the immediate substitution of analytical loads for estimated data. Logically blended loads were inferred by running the multi body full vehicle on virtual road. Virtual roads are made in software for various sorts of conditions like pot opening, herb strike, nation roads, rough road, express expressway roads and city roads. This virtual method for road load data obtaining abbreviated the item advancement cycles and expanded the precision of stress forecast. CAE is a tool which encourages planner to think of first time right design. This additionally calls for high level of trust in CAE simulation comes about which must be accomplished by correlation activities [23]. This test is administrative prerequisite which additionally guarantees that the spot weld joineries have adequate quality. Same test was mapped in CAE and high stress areas were recognized. In test, strain gauging was done at the three chosen areas. Paper features the test versus CAE strain correlation and its findings. The FEM model of fuel tank shell components was utilized to mesh every one of the segments of fuel tank assembly. Seam weld between the top and base shell of the tank were represented by two lines of RBE2 components, showing seam width. Spot welds between baffles and fuel tank were displayed utilizing ACM2 welds. Element size of 5-6 mm was utilized for every one of the parts and component size of 2-3 mm was utilized to show fillet. All beads and fillet were modeled to catch every points of interest of fuel tank. At the strain gauge area mesh was refined to a component size of around 1-2 mm to catch the pressure precisely. Designing a vehicle undercarriage includes meeting various execution necessities identified with different spaces, for example, Durability, Crashworthiness and Noise-Vibration-Harshness (NVH) and additionally decreasing the general weight of case [24].

In regular Computer Aided Engineering (CAE) process, specialists from every area work autonomously to enhance the plan in view of their own space learning which may bring about imperfect or even non-adequate outlines for different areas. What's more, this may prompt increment in weight of case and furthermore bring about extending the general item improvement time and cost. Utilization of Multi-Disciplinary Optimization (MDO) way to deal with handle these sorts of issues is very much recorded in industry. Be that as it may, how to successfully detail a MDO concentrate and how unique MDO plans influence comes about has not been contacted upon inside and out This investigation actualizes different MDO definitions on a set up SUV body outline for additionally weight lessening and execution change. Results from various MDO details are looked at and experiences are given into methods for figuring a MDO issue with a specific end goal to accomplish wanted outcomes. Decreasing the vibrations in the drivetrain is one of the prime necessities in the present cars from NVH and quality viewpoints [25]. The virtual drivetrain reenactment approach to foresee the driveline actuated excitations transmitted to vehicle is created for three cylinder motor utilizing ADAMS View. The acquired mount powers from ADAMS dynamic recreation is connected with the deliberate test information at vehicle level and the great relationship is watched. Paper examines on the system of virtual drivetrain utilizing ADAMS see and the connection of estimated dynamic mount powers with recreation comes about. Fumes framework is one of the complex car frameworks as far as execution and quality forecast because of blend of transient mechanical and warm loads following up on it at the same time [26]. The greater part of car vehicles have fumes frameworks with hot end mounted on motor and chilly end mounted on body or BIW through holders. Another powertrain mounted fumes framework was produced in-house. This fumes framework experienced approval and assessment amid improvement stage. Sturdiness concerns were seen on debilitate framework in track test and rigging shift solidness test. A total water powered servo slowing mechanism recreation demonstrate made out of brake pedal, vacuum promoter, brake ace cylinder, brake pipe, brake wheel barrels, brake calipers is set up in AMESim. The impacts of elastic response plate solidness, elastic valve opening, brake ace cylinder, brake caliper, brake pipe miss happening and grating liner distortion on brake pedal feel are considered in this model [27]. The exactness of this model is checked by genuine road vehicle tests under static and dynamic conditions. The impact of six auxiliary parameters of vacuum supporter, brake pipe and brake caliper on brake pedal feel is broke down in detail. This examination can fill in as imperative reference for acquiring the best brake pedal feel, and furthermore gives the hypothetical premise to pedal test system outline and braking expectation acknowledgment in Brake-by-wire. Tractors are subjected to rock solid cycles which are generally with customary dry write clutches. These kinds of dry clutch when worked in substantial application produce extensive measure of warmth inside shorter timeframe on the surface of rubbing plates [28]. This expansion circle surface temperature which debilitates the grinding material property and holding component prompting disintegration and diminishing the life of clutch. This shortens the clutch life broadly and is a major test to agriculturists and tractor clients. The incessant clutch disappointments builds the working expense, as well as the overhauling of clutch in the tractor fitted with overwhelming connections prompts a higher downtime and administration cost. To beat this test, an inventive arrangement in the oil scatter idea has been developed to give dynamic flow of oil to the multi plate wet clutch rubbing plates while in connected conditions. The framework is outlined such that it removes the oil stream in to the clutch unit while clutch is withdrawn. This oil scatter framework uniformly diverts the warmth produced crosswise over grinding and steel plate surface through the furrow designs in the circles. The centrality levels of the clutch pedal exertion parameters in hard core vehicles with manual transmission [29]. A non-direct multibody dynamic model of the clutch framework is created to demonstrate the impact of clutch framework parameters on clutch pedal execution in a test plan.

The most basic variables are chosen the discharge stack on discharge bearing, mechanical proportion, clutch servo support gaseous tension, water powered proportion, development misfortune proportion, spring powers. Limited component examination (FEA) has been the principle device for enterprises to survey segments and frameworks disappointment and physical conduct [30]. Expanded computational assets, the development of programming bundles and the requirement for more unpredictable applications have added to add new assets to the limited component situation. A standout amongst the most intriguing of those new highlights is auxiliary enhancement, which takes item improvement to an unheard of level by lessening material expenses while thinking about geometrical and assembling requirements. In the present paper, basic advancement is utilized as a device to build up another lever arm for clutch discharge direction. Among the plan imperatives, geometric limitations and also stacking and contact interfaces were considered. A restoration of the firmness of the move fork of a manual transmission utilizing contact design investigation and optistruct. All the subsystem (i.e. synchronizer and the move framework part) are obliged to upgrade the move fork firmness. A-5-speed manual transmission is utilized for instance to outline the reenactment, co-connection and approval of the improvement of the apparatus move fork solidness [31]. The move framework was displayed in the product to group the synchronization constrain, move framework hole and so on with the requirement on the move fork. It is compelled by the synchronizer sleeve and the fork mounting on the apparatus move rail. The synchronizer drive is then connected on the rigging shift fork cushions which are meant the synchronizer sleeve. It has various cushions which come into contact at various event of the synchronization as a result of the changing solidness of the fork. The contact is disseminated to improve the diversion of the fork in the synchronizer for mishandle stack.

The synchronization compel is dispersed over the cushions which are in contact amid the synchronization stage. The fork has a tendency to redirect with the synchronizer sleeve amid synchronization along these lines going about as a damper and putting away vitality. Accordingly the contact examination and optistruct of the change fork guarantees that the gear move fork is improved for firmness and stress in this way supporting in synchronization. A neural system model of a full auto has been produced here based on ADAMS recreation comes about [32].

The model essentially expected for move control ponders, is a totally non-liner display and has 104 degrees of flexibility. ADAMS programming has been utilized to decide the model conduct to particular guiding sources of info. The yield of the recreation program was then used to prepare a neural system built to inexact the model for controller outline and ongoing investigations of control activity. Particular time deferred criticism contributions to the neural system came about a proficient inexact model with great precision for control undertakings. Thus reproduction progressively turns into a focal viewpoint in the vehicle advancement process. With expanding exactness of the single instruments and a brilliant mix of various apparatuses the believability of the entire reenactment affix comes nearer to testing comes about. Moreover the reproduction gives us the likelihood to change early and effortlessly the item credits with respect to usefulness, heartiness, comfort, and so on [33]. The colossal item cost coming about because of a high measure of various test tests can be diminished by an early screening of the coveted item usefulness. Inside General Motors Company-Powertrain a consolidated clutch reproduction approach is utilized which joins the reenactment devices Matlab/Simulink, LMS AMESim, Abaqus, Fortran, StarCCM+, NX Unigraphics to a great improvement process. A dry grating clutch is adjacent to its principle usefulness, assembling the associating join amongst motor and transmission, frequently the weakest connection in the entire power 3D shape. The client desires on the clutch framework are that it is easily operable over lifetime under thought of every single known instance of resiliences out of the serial generation. Logical and numerical investigation is done to think about the conduct of stick-slip and judder wonder amid drawing in and withdrawing of the car clutch. For this reason, a four level of opportunity torsional control prepare lumped mass model was created [34].

This torsional vibration framework incorporates motor flywheel; clutch, equip box and vehicle drive line, which are associated with each other by shafts. Condition of movement of the framework is created and at first a security examination is done for different angles of coefficient of erosion utilizing Eigen esteem investigation. Afterward, a numerical reenactment is completed to examine the judder and stick-slip wonder utilizing economically accessible scientific instrument MATLAB. It is watched that the clutch stick-slip is expanded with increment in outside torque and clutch weight changes. A control situated model of a Dual Clutch Transmission was created for constant Hardware on the up and up (HIL) applications. The model is an inventive endeavor to repeat the quick progression of the activation framework keeping up a stage estimate sufficiently vast for continuous applications [35]. The model is equipped for duplicating the conduct of the genuine framework amid adaption systems performed by the TCU under specific conditions, i.e. synchronizer position identification and clutch weight trademark recognition. Being founded on physical laws, in each condition the model recreates a conceivable response of the framework to the forced disappointment or move, as exhibited by the likelihood of playing out a total new programming discharge test in completely programmed mode. For ECU (Electronic Control Unit) improvement of LuK Electronic Clutch Management an equipment on the up and up application was created from a current disconnected reenactment condition [33]. The advancement procedure, the HIL-structure, models, issues in executing ongoing models, assessment of models and correlation of numerical combination strategies are depicted..

2.1 Importance of the proposed project in the context of current status:

Past studies include the analysis of dual clutch pedal effort only through simulation. Some research work was also published through FE technique. However, it was not validated with experimental results. In the present study, validation of experimental results will be done with the help of computational method which can optimize dual clutch pedal effort. Present study also involves the whole clutch assembly for analysis through both computational and experimental method. Whereas, in the past studies, only one or two parts of the clutch assembly (conical spring, clutch lever) were tested through simulation or experimentation.

The importance of the project is in the context of current status of the Escorts tractor clutch pedal. It plays a very big role in sale of tractor market. Research project presented here is directly connected with the current status of the tractor dual clutch pedal effort reduction.

One of the most frequent complaints about clutch is slipping of clutch. This is often caused by poor driving habits. This problem is also common when inexperienced drivers operate the vehicle. Timely attention to clutch slipping issues will help you save yourselves from expensive repairs.

Slipping clutch could also be caused due to wear and tear. In case the clutch or the vehicle itself is new and if you are facing slipping clutch issues then you need to get an expert to diagnose the problem to establish the underlying issues that cause slipping clutch problems. Improper clutch disengagement and then engagement is the main cause of the said problem.

Proposed work, also involves the improvement in efficiency of the present model of the clutch pedal of the tractor. At present, load applied on the clutch pedal is 64 kgf and this load is very high for driver. Due to regular usage, drivers feel knees pain and then make it very difficult to drive.

2.2 Objective of Research & Application

Based on the literature and problem in the tractor industries, the following objectives are proposed for this work.

- To reduce the clutch pedal effort
- To increase the efficiency of single plate friction clutch
- To reduce the drivers fatigue in clutch operation.

2.3 Application of objectives

- Optimize product can be directly implemented in agri machinery and other heavy engine clutches.
- Concept may be useful in reducing fuel consumption in passenger vehicle also without any extra power consumption.

2.4 Project location:

Project was carried out at Escorts Corporate Limited, Faridabad and Thapar Institute of Technology, Patiala. Conceptualization, design & optimization of the proposed design were performed in CAE department of Escorts limited, Faridabad.

CHAPTER- 3

Design and analysis

3.1 Existing model and new model of clutch release fork

The existing model of fork cylinder is shown in fig. 3.1 Contact between the clutch plate and fork bearing was high hence the travel of clutch pedal increase and more effort is required to

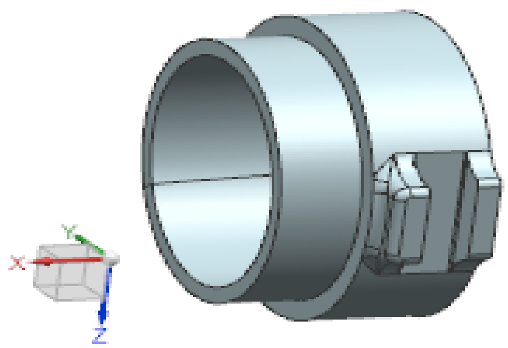

Fig. 3.1 Clutch release fork cylinder (Existing design)

Actuate the clutch. The idea behind the new design is to increase the length of the fork cylinder in axial direction so as to reduce the clutch pedal travel. fig. 3.2 shows the new design of the fork cylinder.

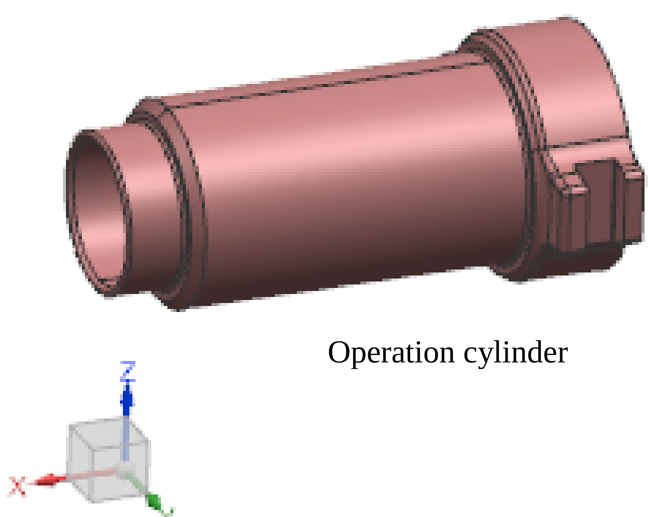

Fig. 3.2 Clutch release fork cylinder (New design)

As shown in fig. 3.1 and 3.2 the dimensions of the parts are as following

- Length of cylinder in old design = 17.5 mm
- Bearing diameter in old design = 65 mm

After proposed changes the dimensions are

- Length of clutch release fork cylinder = 88.6 mm
- Diameter of clutch release fork bearing = 42 mm
- Diameter of clutch release fork cylinder = 57 mm

3.2 Assembly of existing and new design model of clutch release fork

Assembly of clutch release from as per the old design is shown in fig. 3.3, which consists of shorter cylinder connected through a single bolt with the fork lever. Whereas new design assembly shown in fig. 3.4 depicts the use of two bolts with fork lever.

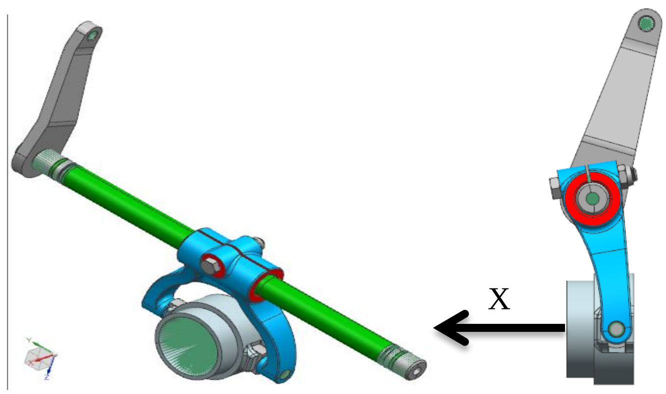

Fig. 3.3 Existing model of clutch release fork and its side view

It will improve the deflection and stresses in this design. This design make more stable as compare to old design of clutch release fork.

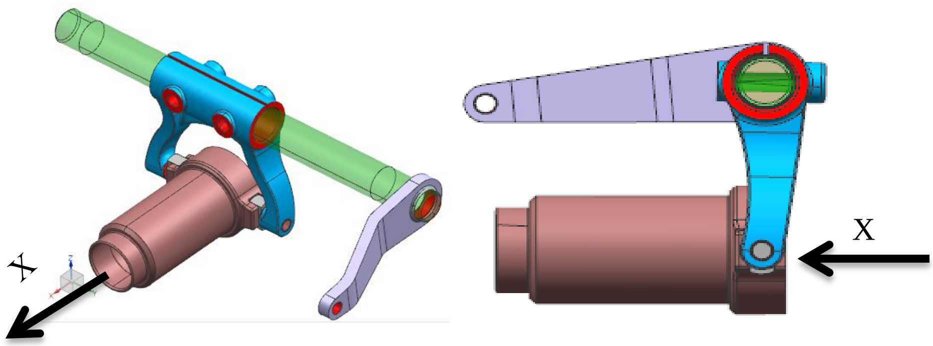

Fig. 3.4 New design model of clutch release fork and its side view

After the modeling static analysis has done to check the deflection and stress of the new design clutch release fork.

3.3 Finite element modeling and analysis

3.3.1 FE analysis of existing model of clutch release fork

The durability analysis process comprised of following steps in computer Aided Engineering (CAE) Analysis.

- Solid modeling of existing design.
- Finite Element (FE) Modeling.
- Structural Analysis.
- Linear static analysis for von-mises stress distribution pattern.
- Normal mode analysis of component for identifying most damaging frequencies fatigue.
- Prediction of probable failure zone.
- Modification in design and reanalysis.
- Finalization of modified design.

Solid model of clutch release fork can be created in NX modeling software and the transferred it to FEM software fig. 3.5. Clutch release fork is meshed with linear six noded tri elements. The clutch release fork restrained at the center point of operation cylinder and the center point connect with RB 2 connection with cylinder inner surface. Fork lever fixed in all direction. Translation is free at X direction on lever connecting link.

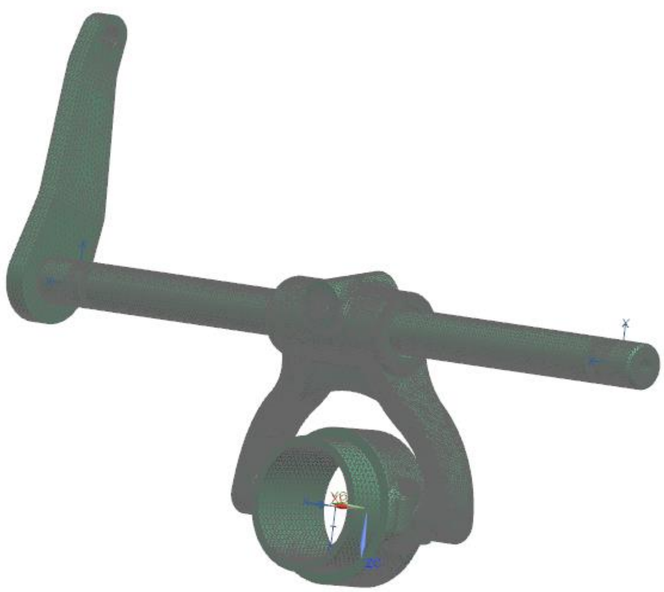

Fig. 3.5 FE model of existing clutch release fork

Contact between fork and operation cylinder was defined using surface glue boundary condition. Now the load are applying in X direction of fork contact surface in horizontal direction. The bolt connection was made between the clutch release fork and lever. Beam elements used for connecting the both components.

3.3.2 Boundary condition for existing model of clutch release fork is

Load of 2250N was applied on fork finger. The calculation the applied load was obtained from experimental calculation in Escorts limited.

Table no. 3.1 Load value for fork finger

Sr. No.	Load	Direction
1.	2250 N	X

Table no. 3.2 Boundary condition for clutch release fork

Sr. No.	Constraints	Direction
1.	User Define	Y (Free)
2.	Fixed	Lever
3.	User Define	X (Translation)

The load is applied on the clutch release fork. The load value is defined in the table no. 1. It is the value we need to apply there for disengage the clutch drive mechanism. This analysis doing presently followed by Escorts limited. Now this value is consider for analysis of clutch release fork. All the boundary conditions were used as per ISO standard (ISO 10998:1995) values for tractor clutch assembly mechanism.

3.3.3 Clutch release fork computational analysis of existing design

Linear static analysis gives von-mises stresses and deflection in this design. All results are shown in fig. 3.6.

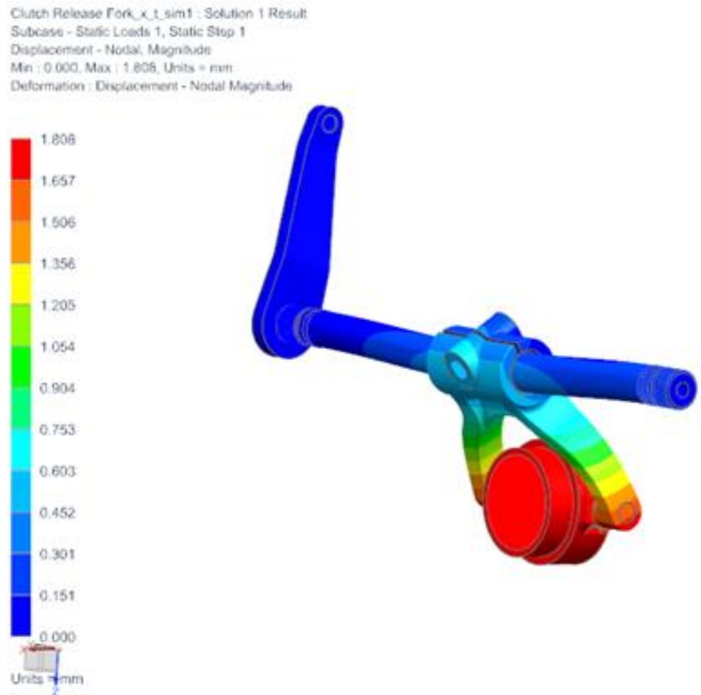

Fig. 3.6 CAE model of Clutch release fork of existing design

3.4. Deflection analysis

The maximum deflection at the location of fork and cylinder contact is 1.806 mm. Deflection of 1.806 mm is very high & need to be reduced. A new design for fork was analyzed again by applying same loading and boundary condition. New design is analysiszed for deflection and stresses.

3.4.1 Stress analysis of existing model of clutch release fork

The existing clutch release fork produce more stress to the limit value so again a new design of clutch release fork was made and applied same loading and boundary condition to calculate stresses. As per the analysis the maximum stress of 2292.55 N/mm^2 was found at the location of fork finger hole.

Max. Stress: 2292.55 N/mm^2

Min. Stress: 0.00 N/mm^2

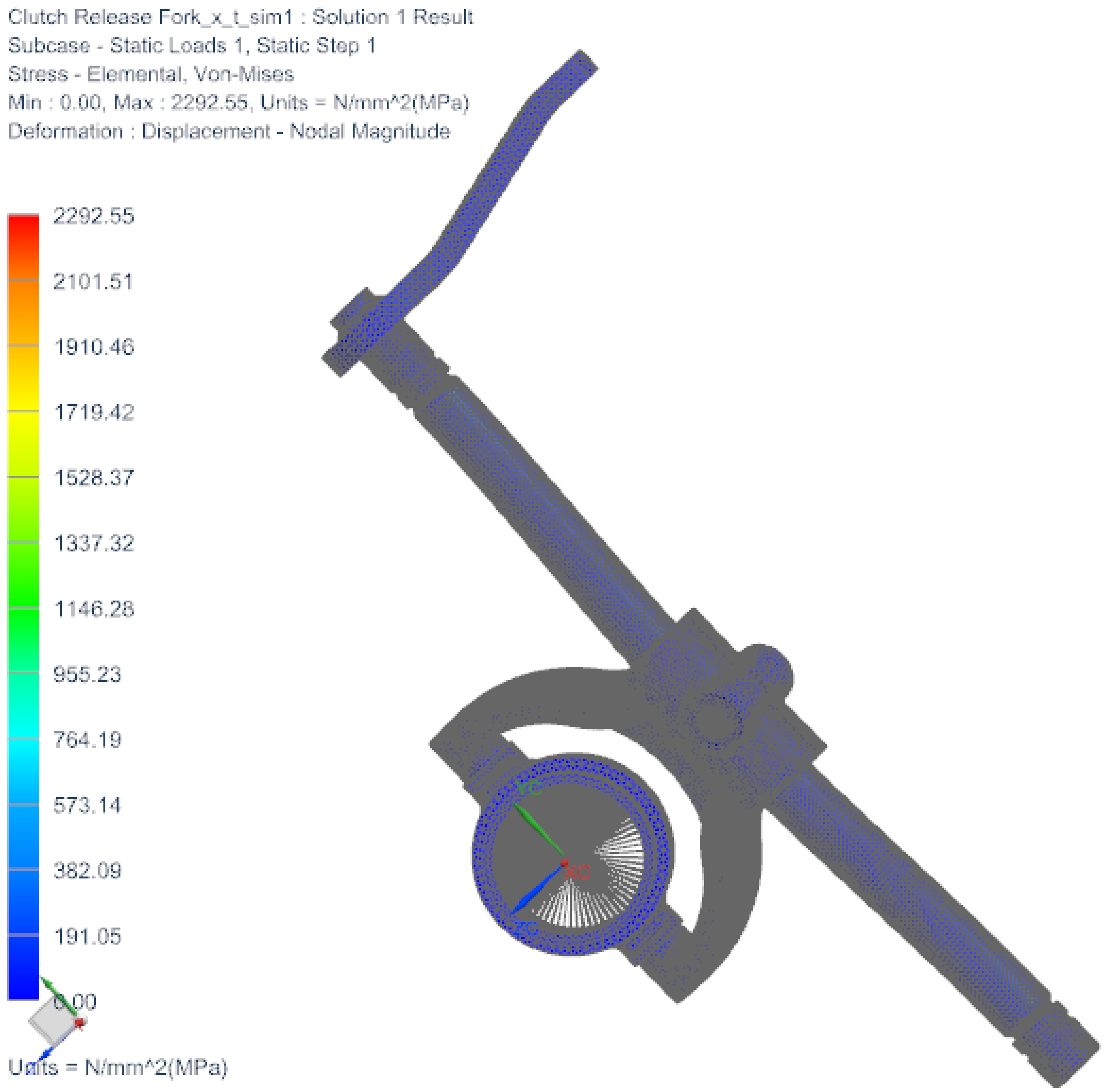

Fig. 3.7 stress analysis of existing model of clutch release fork

In the existing model of clutch release fork analysis the stress by using of computational method. The maximum stress value is 2292.55 N/mm^2. As compare to new model of clutch release fork the value of stress very high.

3.5 FE analysis of new design of clutch release fork

The durability analysis process is comprised of following steps in computer Aided Engineering (CAE) Analysis.

- Solid modeling of new design.

- FE (Finite Element) Modeling.
- Structural Analysis.
- Linear static analysis for von-mises stress distribution pattern.
- Normal mode analysis of component for identifying most damaging frequencies fatigue.
- Prediction of probable failure zone.
- Finalization of modified design.

Solid model of clutch release fork was created in NX modeling software and then transferred it to FEM software as shown in fig. 3.5. Clutch release fork is meshed with linear six noded tri elements. The clutch release fork restrained at the center point of operation cylinder and the center point connect with RB 2 connection with cylinder inner surface. Fork lever fixed in all direction. Translation is free in X direction on lever connecting link.

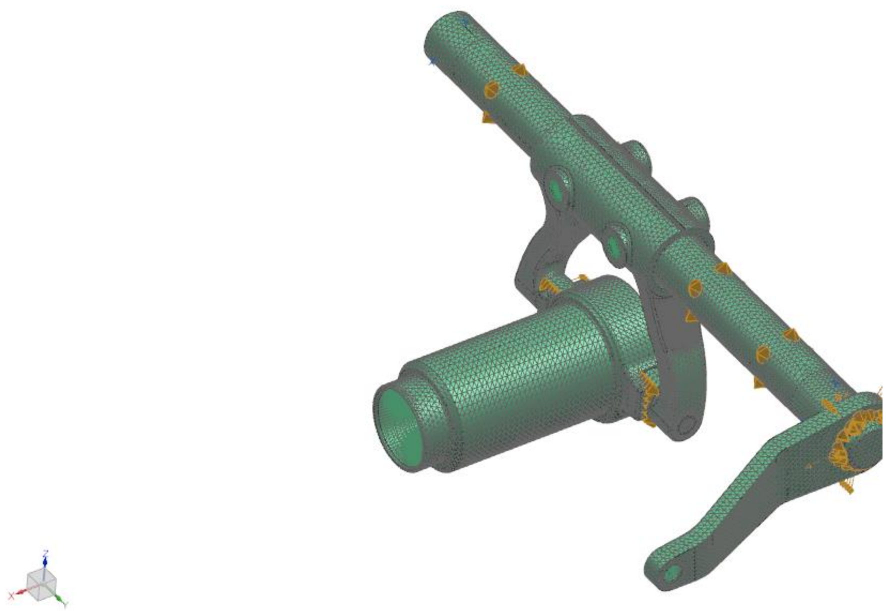

Fig. 3.8 FE model of modified design of clutch release fork

Define the contact between fork and operation cylinder by using of surface glue. Now the load are applying in X direction of fork contact surface in horizontal direction. The bolt connection is making between the clutch release fork and lever. Beam elements used for connecting the both components.

3.6. Boundary condition for new design model of clutch release fork

Load of 2250N was applied on fork finger. The calculation the applied load was obtained from experimental calculation in Escorts limited.

Table no. 3.3 Load value for fork finger

Sr. No.	**Load**	**Direction**
1.	2250 N	X

Table no. 3.4 Boundary condition for clutch release fork

Sr. No.	**Constraints**	**Direction**
1.	User Define	Y (Free)
2.	Fixed	Lever
3.	User Define	X (Translation)

The load is applying on the clutch release fork. The load value is defined in the table no. 3. It is the value we need to apply there for disengage the clutch drive mechanism. This analysis doing presently followed by Escorts limited. Now this value is consider for analysis of clutch release fork. All the boundary conditions were used as per ISO standard (ISO 10998:1995) values for tractor clutch assembly mechanism.

3.6.1 Deflection analysis of modified design

Deflection analysis is shown in fig. 3.9

- Max. deflection - 1.293 mm
- Min. deflection - 0.0 mm

The using of computational method I found the maximum deflection in clutch release fork. The value is 1.293 mm is the max deflection and minimum deflection is 0.00 mm. values of deflection in the new design are less than the old design. Hence, the strength of the new design is said to be increased.

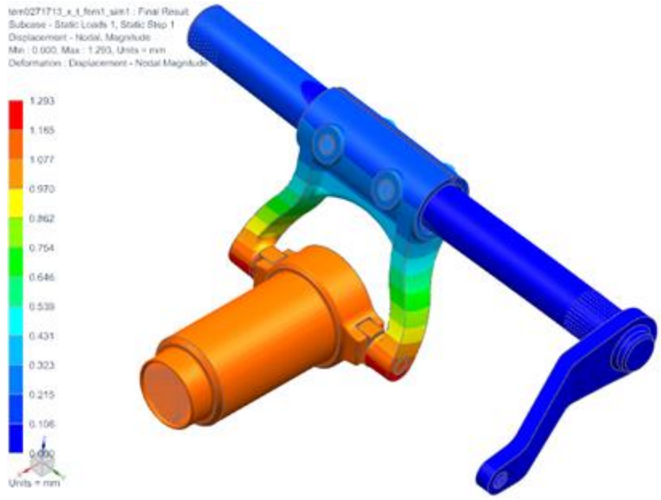

Fig. 3.9 Clutch release fork of modified design

3.6.2 Stress analysis of new design model of clutch release fork

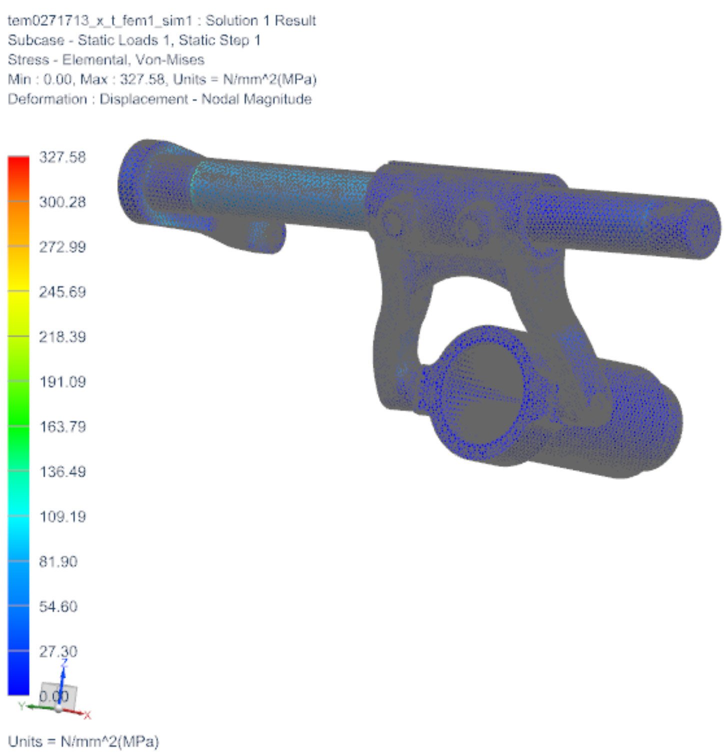

Fig. 3.10 Stress analysis of modified design of clutch release fork

The modified clutch release fork produce less stress to the limit value so values of stresses in the new design are less than the old design of clutch release fork. Hence, the strength of the new design is said to be increased. As per the analysis the maximum stress of 327.58 N/mm^2 was found at the location of fork finger hole.

3.7 Comparison

Old design of clutch release fork requires more clutch pedal travel and need more load as shown in fig. 3.3, length of clutch release bearing fork is less as compare to new model of clutch release bearing fork. The existing model requires high leg power for disengaging and engaging clutch. The pedal travel also increases in this model for engaging and disengaging of dual clutch PTO shaft require more pedal load. It will also decrease the efficiency of transmitting power from engine to transmission system. Theoretical and computational data of new model of clutch release bearing fork is show in fig. 3.4 which reduces the pedal effort or pedal travel. The length of new clutch release fork will increase. The efficiency of dual clutch also increases. In new model contact between fingers and release bearing is very less, so that pedal travel and pedal effort decreases.

The clutch release bearing is in direct contact with the finger of the clutch and materials in contact suffer a relative motion. Thus the contact surface and the relative motion are important parameters for correct operation and to avoid wear. The "throw-out bearing" is the heart of clutch operation. When the clutch pedal is depressed, the throw-out bearing moves toward the flywheel, pushing in the pressure plate's release fingers and moving the pressure plate fingers or levers against pressure plate spring force. This action moves the pressure plate away from the clutch disc, thus interrupting power flow.

The deflection of the existing model is 1.8 mm. In the new model of clutch release fork deflection is 1.293 mm. So the deference between the existing clutch release fork and new design model is 0.507 mm.

The stress of the existing model is 2292.55 N/mm^2. In the modified design of clutch release fork stress is 327.58 N/mm$^{2.}$ Value of stress in the new modified design is less than the old design. Hence, the strength of the new design is said to be increased.

CHAPTER-4

Analysis of components of clutch pedal assembly

All the clutch pedal assembly and kinematic analysis was performed.

4.1 following parameters were analyzed using ADAMS software

- The efforts of the clutch
- Travel of clutch release fork
- Torque
- Pedal angular travel degrees
- Total distance

4.2 Simulation of clutch release fork with clutch linkage mechanism

The kinematic simulation of clutch release fork has been performed to find out effort required for clutch engages/disengages driving mechanism. The mechanism is Show in fig. 4.1

Fig. 4.1 ADAMS analysis model of clutch release fork

4.2.1 The boundary condition and results analysis of clutch release fork

For the analysis of clutch efforts, boundary condition to the FE model has been applied. Load of 2250 N was applied on the clutch release fork. The travel value of 10 mm was used in the analysis as per the requirement of Escorts limited.

According to travel value of 10 mm, value of angular moment of the clutch pedal was obtained. The angular moment of clutch pedal is show in fig. 4.2.

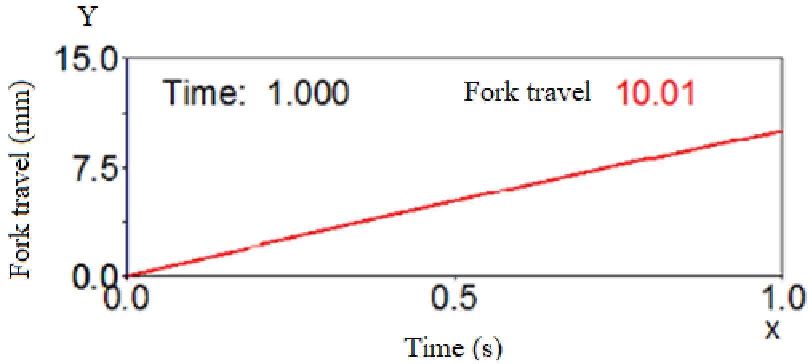

Fig. 4.2 Travel of clutch release fork

Values obtained from graph matched with the travel value of 10.01 mm and actuation time 1.0 sec of the clutch release fork.

When provide the travel value to the clutch release fork then clutch will engage or disengage. Now there is need to calculate angular travel for clutch pedal.

By using iterative method to find out the angular moment of the clutch pedal, different value of angular moment were applied to match the travel value of clutch release fork. The value of angular moment is shown in fig. 4.3

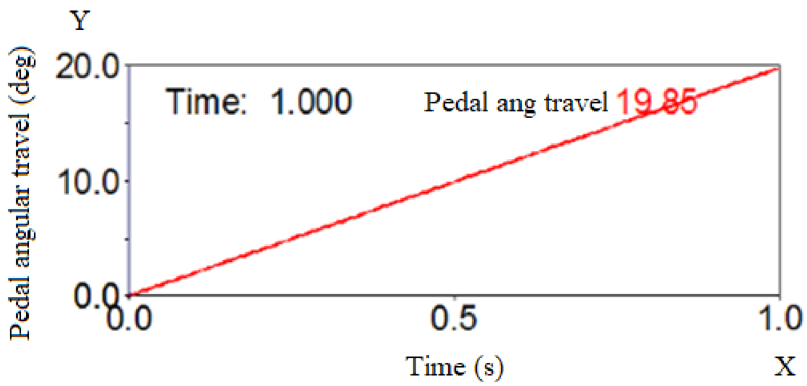

Fig. 4.3 Pedal angular travel degree

The value of pedal angular travel = 19.85 degree

Clutch need angular travel of degree to 19.85 engages or disengages.

4.2.2 Clutch pedal effort

In ADAMS analysis, when applying the 2250 N load on the clutch release fork the results as shown in fig. 4.6. The current effort is 16.69 kgf and time take for engage or disengage clutch is 1.0 sec.

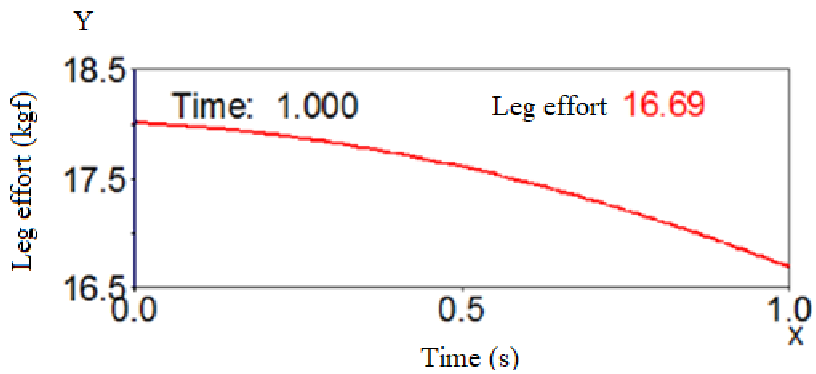

Fig. 4.4 Efforts v/s time graph

Clutch pedal effort = 16.69 kgf

Time = 1.00 s

In existing model we require more travel as compare to modified model, so we need to provide more angular moment to the existing model of clutch release fork but in new modified model of clutch release fork. Increased the length of clutch release fork then the results come with decrease the travel and reduce the efforts of clutch pedal. In this model travel decreases and then clutches pedal need less effort of leg. The analysis of these simulated muscular forces gave an insight into the way a clutch pedal operation is performed in terms of muscular exertion and coordination.

4.2.3 Torque analysis of clutch release fork

After applying force on the clutch release fork the torque has been calculated as show in fig. 4.5.

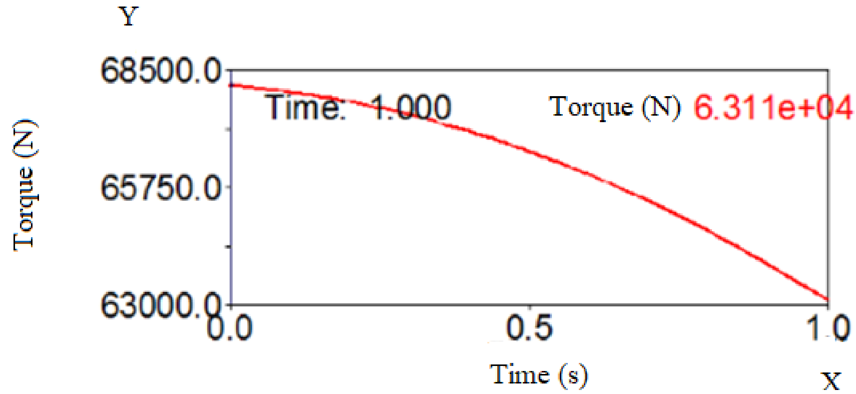

Fig. 4.5 Torque analysis for clutch

The Total torque 68500.0 N is applied in the small actuation time of 1.0 sec.

Time = 1.00 Sec

4.2.4 Total distance travelled by clutch pedal

By simulation the total distance travelled by clutch pedal is show in fig. 4.6

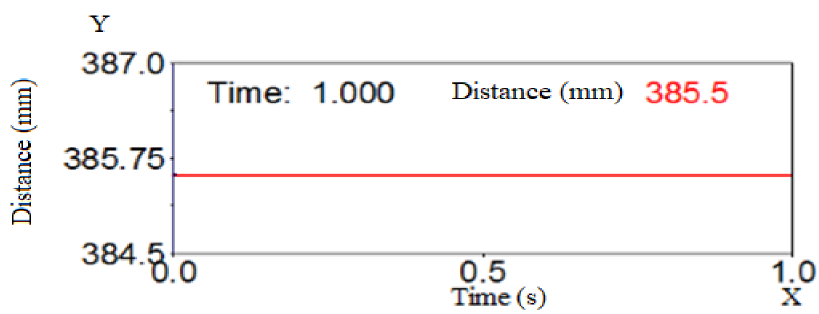

Fig. 4.6 Total length of clutch release fork

Calculated total length of clutch pedal in order to find total torque required for clutch engage or disengage drive mechanism.

Total pedal length = 385.5 mm

4.2.5 Analysis of clutch effort and travel of the clutch

In this analysis it is observed that when travel of clutch release fork decrease then effort will decrease. There are 16.69 kgf efforts and travel is 10 mm shown in fig. 4.7.

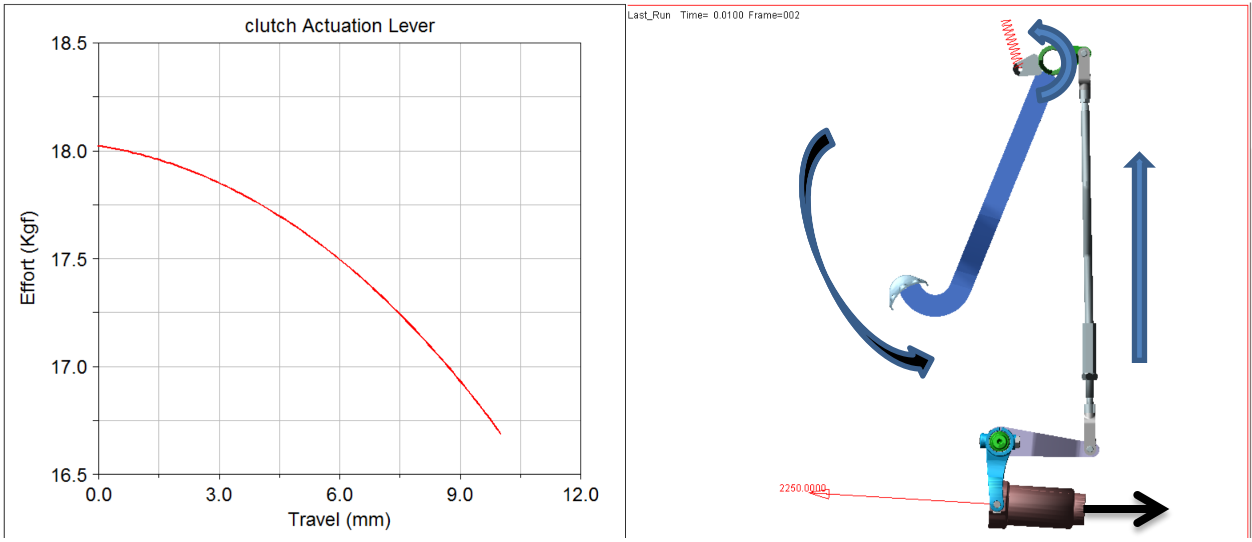

Fig. 4.7 Clutch travel and effort analysis

CHAPTER- 5

DESIGN -1 design & analysis of effortless actuation mechanism

5.1 A new design of clutch linkage with zero human leg efforts

A new model without clutch pedal is proposed in this design – 1. In this model there is no need of clutch pedal because there is inventing effort less clutch by use of electric Motor. The electric Motor provides the power to clutch for engage or disengage drive mechanism as show in fig. 5.1.

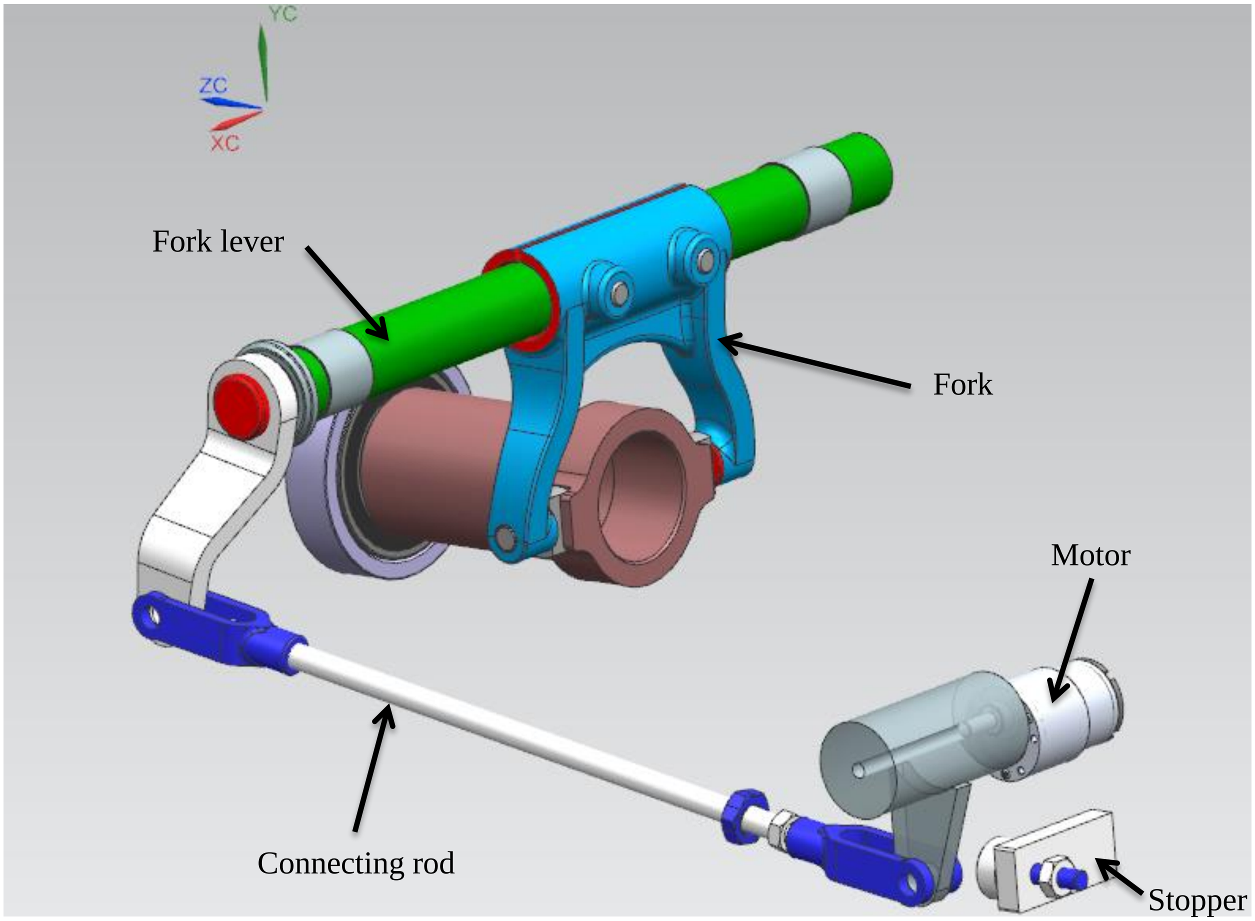

Fig. 5.1 New innovative model of clutch release fork with electric motor

In this design there is need of motor for actuation of clutch release fork to engage or disengage the clutch drive mechanism. A small motor with high torque is required to actuate the clutch fork to engage or disengage the clutch drive mechanism.

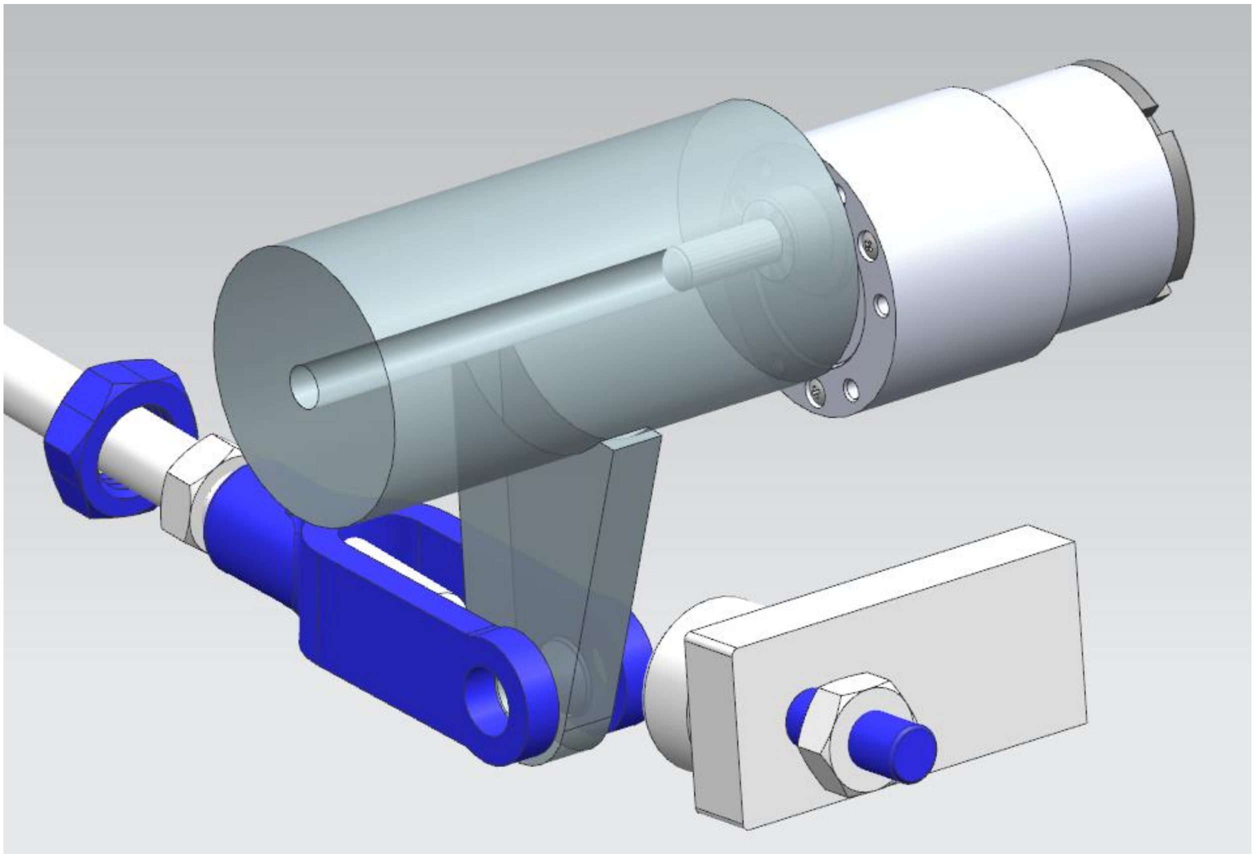

Fig 5.2 Feature view of motor and linkages

5.2 Feasibility study of motor

After the analysis it is observed that in this model low RPM and high torque motor. But this combination is difficult to combine, low rpm and high torque. So, there is need of gear box to control or increase torque to provide requires power to the clutch release fork. Controller is required to control the rpm of the motor and there is need to engage or disengage clutch at 6 rpm. Low RPM and high torque motor is very costly and required high efficient controller, so this model is rejected because it is very costly to apply on pedalless clutch system. In the next section, a new design “Design – 2” is tested with pull type solenoid to provide the power to the clutch release fork to engage or disengage the drive mechanism.

DESIGN– 2 Solenoid actuated lever mechanism

5.3 CAD design of solenoid model actuation lever mechanism

A new concept of clutch linkage with zero human leg efforts is design without clutch pedal. In this model there is no need of clutch pedal as effort less clutch is actuated use of electric solenoid. The electric solenoid provides the power for the clutch for engage or disengage drive mechanism as show in fig. 5.3.

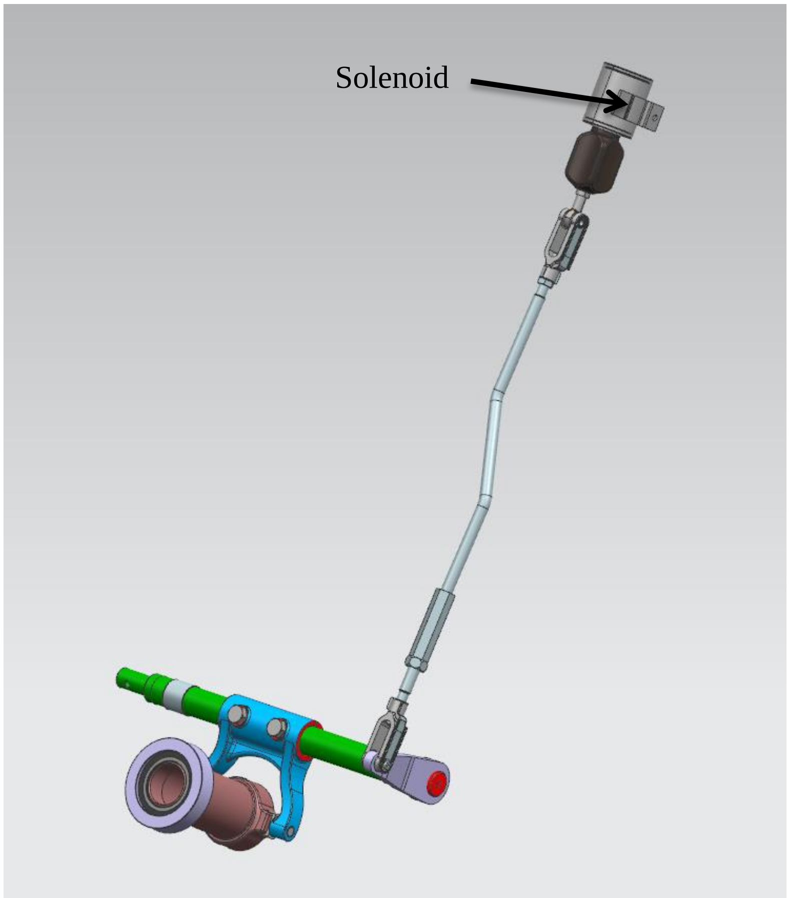

Fig. 5.3 New innovative model of clutch release fork with electric solenoid

In this innovated model the travel of clutch release fork is initiated using solenoid. Solenoid pulls the clutch fork connecting rod to engage or disengage the clutch derive mechanism. Solenoid provides the linear motion and clutch release connecting rod translate it from solenoid to clutch release fork. This is the process for clutch engage or disengages by using electric solenoid. This model decreases the human efforts.

5.4 Working of solenoid

Solenoid is a coil wound into a tightly packed helix. In, term of physics, it refers to a coil whose length is substantially greater than its diameter, often wrapped around a metallic core, which produces a uniform magnetic field in a volume of space (where some experiment might be carried out) when an electric current is passed through it. A solenoid is a type of electromagnet when the purpose is to generate a controlled magnetic field. If the purpose of the solenoid is instead to impede changes in the electric current, a solenoid can be more specifically classified as an inductor rather than an electromagnet.

5.5 CAD design of solenoid

Drawing of solenoid is shown in fig. 5.4, and 5.5

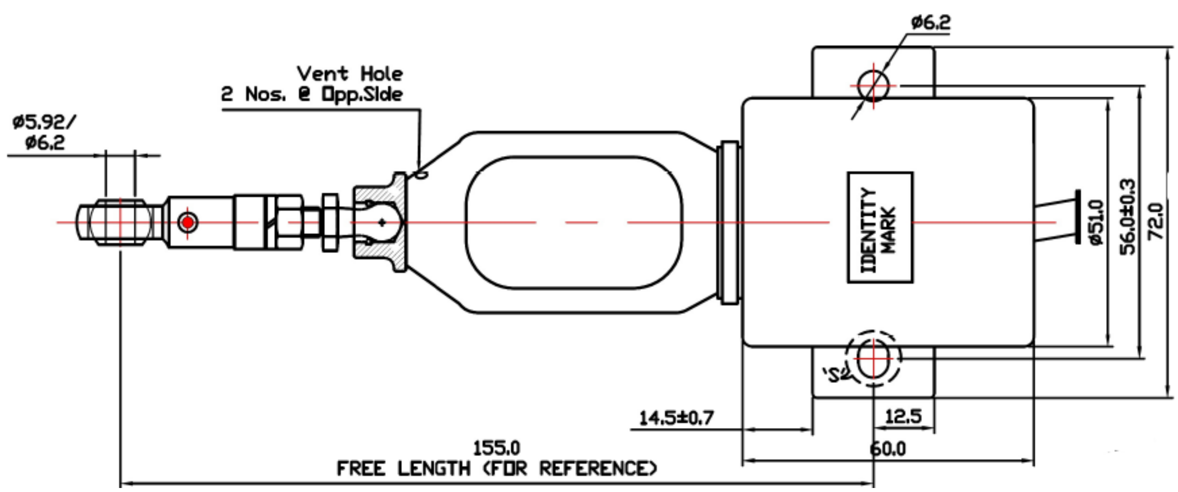

Fig. 5.4 Free length of solenoid linkages

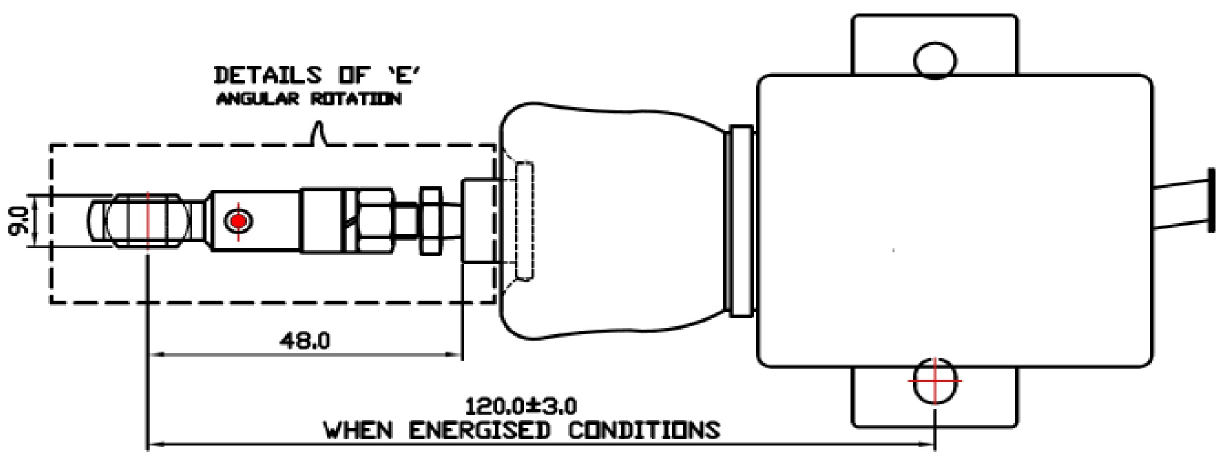

Fig. 5.5 Solenoid in working condition

5.5.1 Components of solenoid

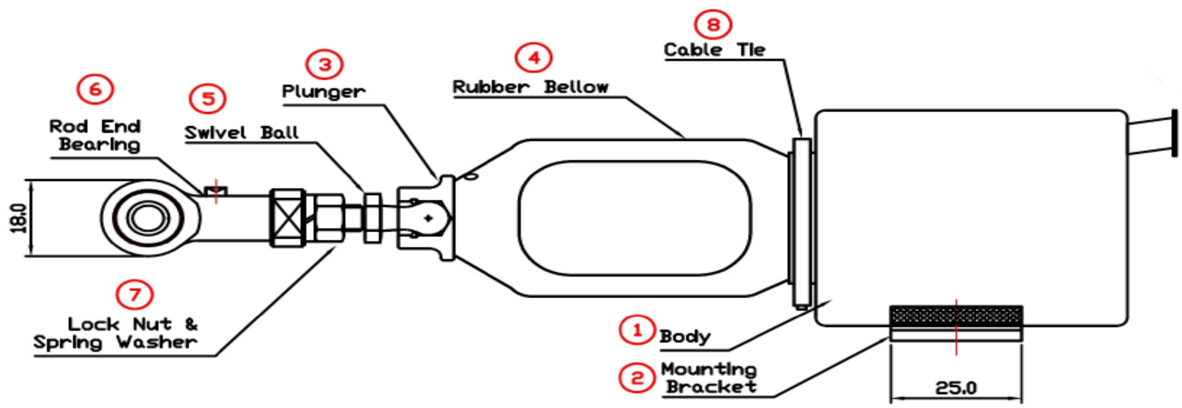

Fig. 5.6 Name of components

1. Body
2. Mounting bracket
3. Plunger
4. Rubber bellow
5. Swlvel ball
6. Rod end bearing
7. Lock nut & spring washer
8. Cable tie

5.5.2 3D CAD model of solenoid

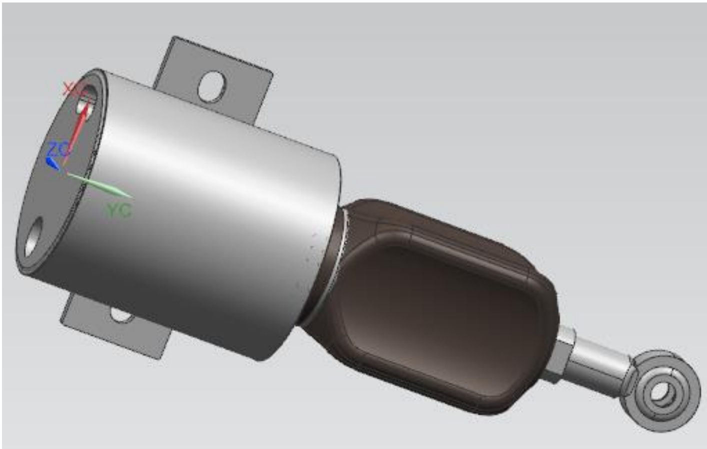

Fig. 5.7 CAD model of solenoid

5.6 Simulation of clutch release fork with Solenoid clutch linkage mechanism by using ADAMS

This analysis is performed to find out the torque required to engage or disengage the clutch and also the travel of solenoid.

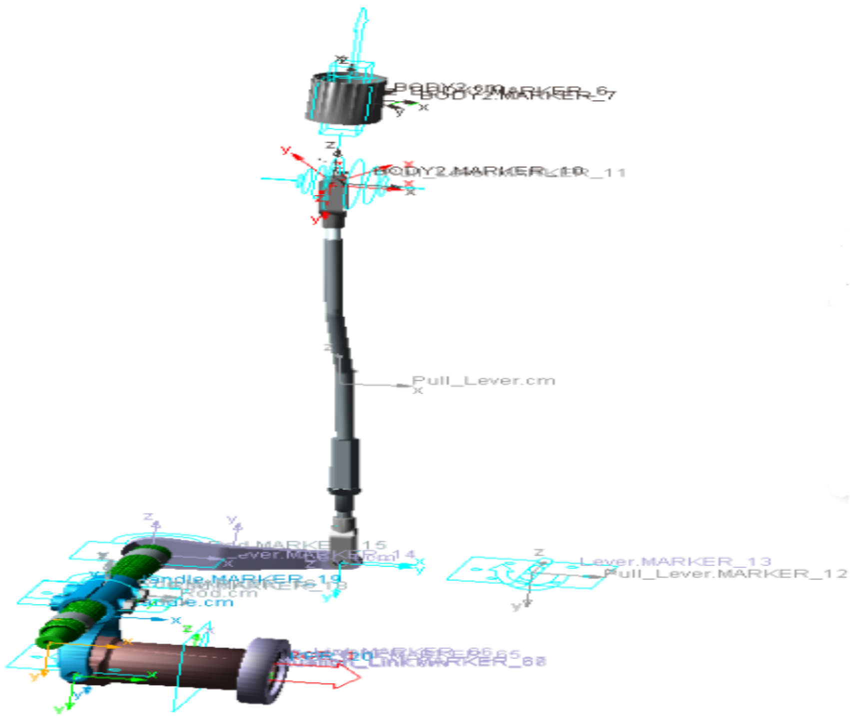

Fig. 5.8 ADAMS analysis of clutch release fork

Fig. 5.9 shows the graph of travel length by the actuation of solenoid. Similarly fig. 6.10 shows the constraint point on the complete assembly.

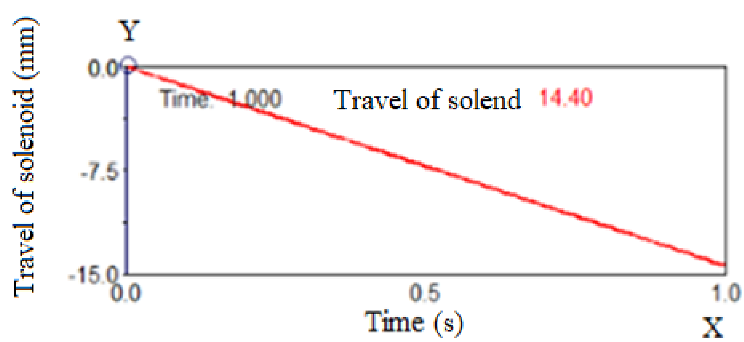

Fig. 5.9 Travel of solenoid

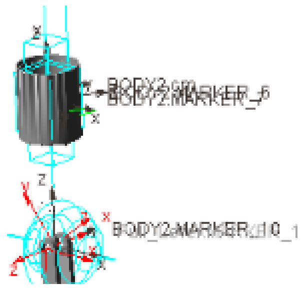

Fig.5.10 Solenoid

It is observed that to obtain the required travel of clutch release fork to engage or disengage the clutch.

Solenoid travel of 14.40 mm is required. Now this is the actuation of solenoid needed to engage or disengage the clutch. The solenoid pulls (14.40 mm) connecting rod. The connecting rod connected with the clutch release fork. The connecting rod changes the motion between solenoid and clutch release fork.

5.6.1 Analysis of clutch release fork travel

Analysis of clutch release fork travel is represented in fig. 5.11. This travel is needed to engage or disengage clutch drive mechanism. The graph goes to 0 to 10.01 mm in one second to engage clutch drive mechanism.

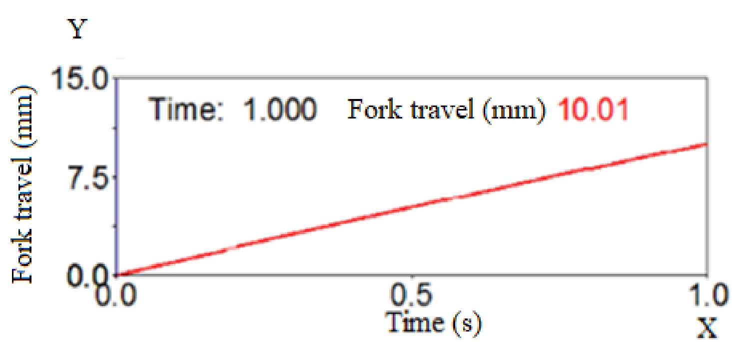

Fig. 5.11 Travel of clutch release fork

In which graph represents the value of clutch release fork after applying the travel value is 10.01 mm and when this travel value is applied to the clutch release fork then clutch is going to engage or disengage.

5.6.2 Torque analysis of clutch release fork

When we apply force on the clutch release fork the torque has been calculated as show in fig. 5.12.

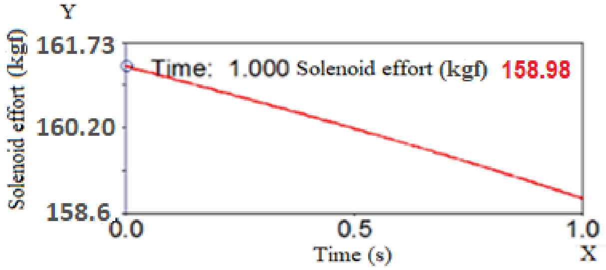

Fig. 5.12 Effort required for clutch engage or disengages

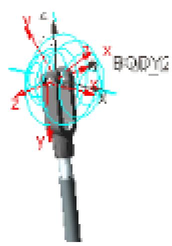

Fig. 5.13 Position of torque require to engage or disengage clutch

Position with 158.98 kgf torque shown in fig. 5.13 that is very high torque coming in that position so the required torque as solenoid should be of very high capacity. Then some changes in length are iterated to get the required values, as shown in fig. 5.15.

5.6.3 Efforts analysis of solenoid

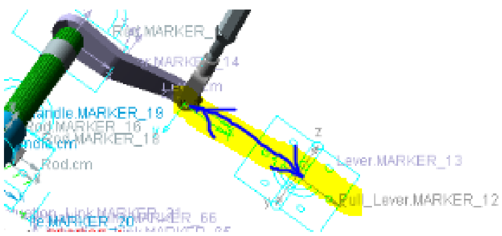

Fig. 5.14 Increase the length of connecting lever

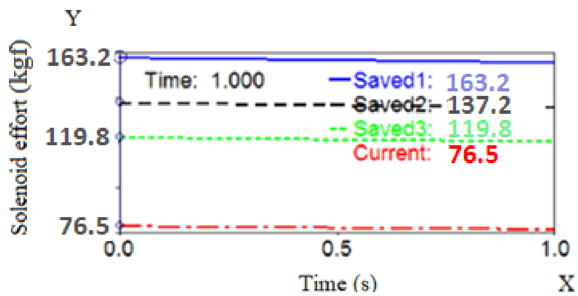

Fig. 5.15 After changed length of lever

Various lever lengths are iterated to get the suitable torque value. But with increase in leverage value of lever the value of torque is decreased. When increased the length or increase the leverage value of lever then the value of torque is decreased. However the obtained value is sufficient for this design.

Table no. 6.1 Lever length difference

Sr. no.	Lever length	Torque
1.	70 mm	163.2 kgf
2.	100 mm	137.2 kgf
3.	120 mm	119.8 kgf
4.	140 mm	76.5 kgf

It can be seen from the values of torque as shown in table 6.1 that with increase in length of lever there is decrease in torque at solenoid.

DESIGN- 3 Reduction of solenoid effort through linkage design

5.7 New design of clutch linkages with electric solenoid

In this model there is increase in length of lever and change the position of solenoid as shown in fig. 5.16 The solenoid pulls the lever then lever move downward and clutch has been engage or disengage the drive mechanism.

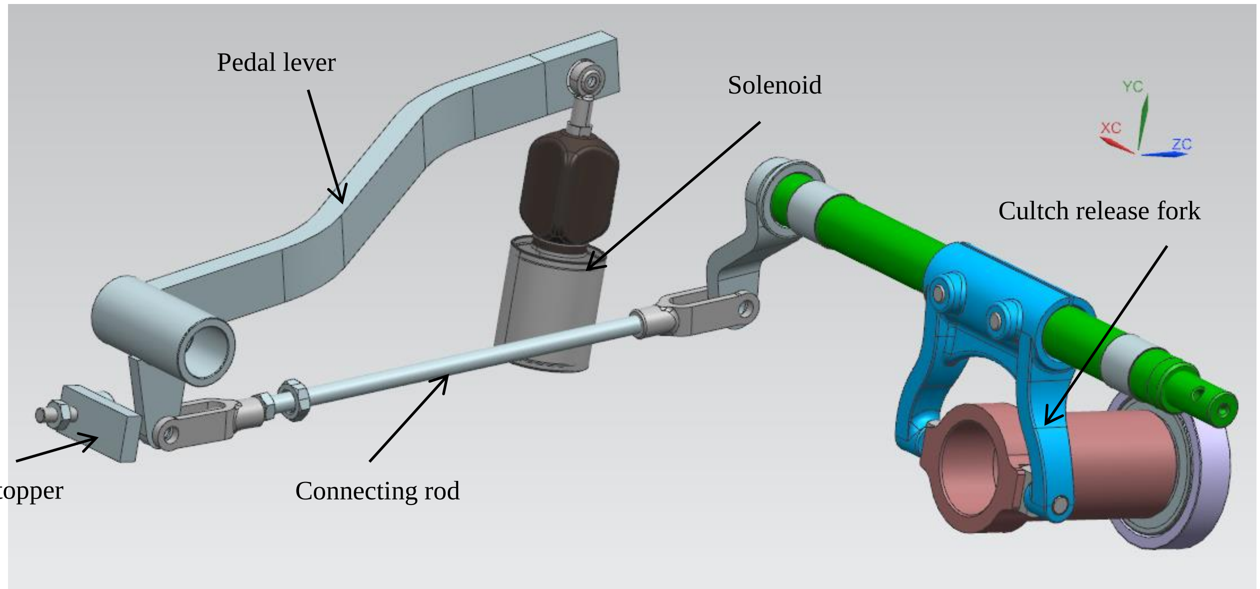

Fig. 5.16 3D CAD model of clutch release fork with solenoid

In this model, pedal lever has been randomly removed and cut section is used to attach the lever for solenoid actuation. This was done to study effect of solenoid on clutch mechanism when compared to legacy clutch mechanism. Solenoid is attached by the help of two bolts and it pulls point 'A' downward which further provides the motion to clutch release fork to engage and disengage the clutch drive mechanism by the help of arms mechanism.

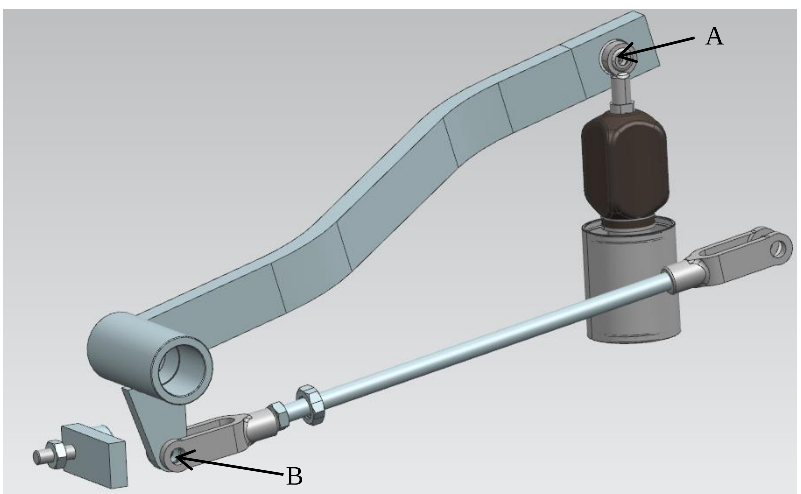

Fig. 5.17 Linkage mechanism for clutch release fork of design – 3

Link ‘A’ is connected with pedal lever with help of bolt connection. Link ‘B’ is connecting with connection rod with help of bolt. Solenoid pulls the link ‘A’ downward link ‘B’ revolve as shown in fig. 5.22.

5.8 Simulation of design - 3 linkages mechanism

After design the new position of solenoid analysis on ADAMS kinematic simulation of the clutch release fork is shown in fig. 5.18.

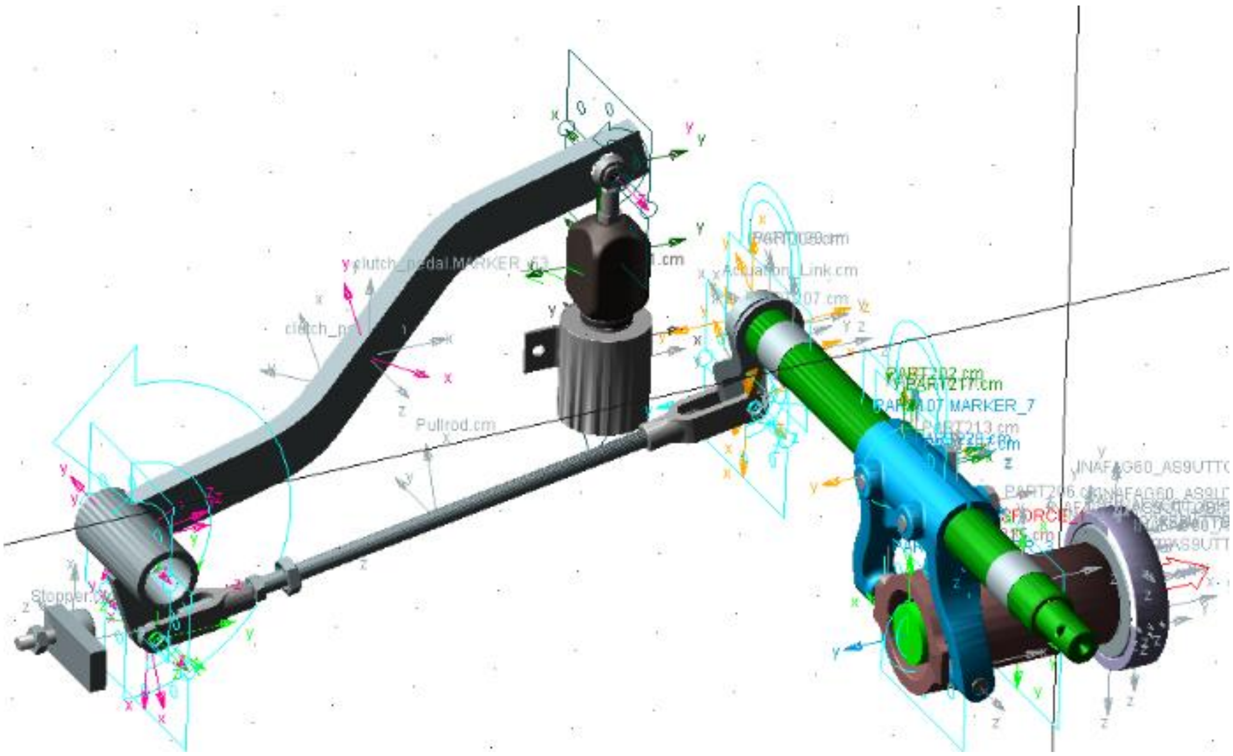

Fig. 5.18 Simulation of design-3 clutch release fork with solenoid

5.9 Analysis of efforts require by solenoid to pull the clutch lever

In that position solenoid required the effort to pull the clutch fork lever shown in fig. 5.19. The efforts have been showing in the graph this effort value by using of ADAMS simulation of the clutch release fork.

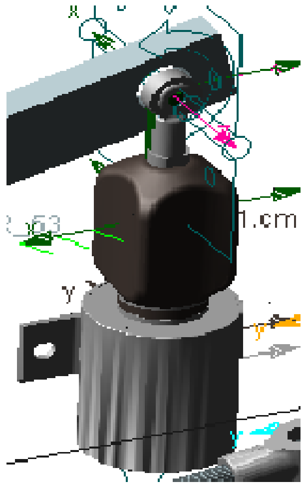

Fig.5.19 Efforts position for solenoid

5.9.1 Required effort for solenoid to engage or disengage the clutch

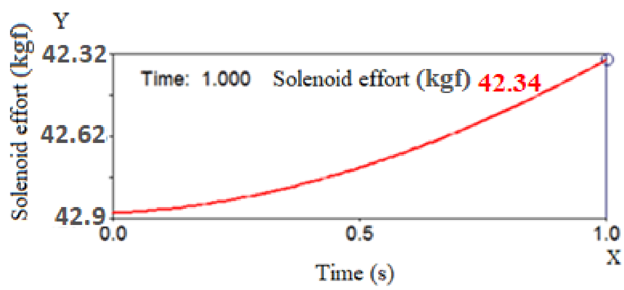

Fig. 5.20 Solenoid efforts for clutch

Effort required for actuation of clutch is shown in fig. 5.20.

The Solenoid effort is 42.34 kgf

In this model there is need of 42.34 kgf to engage or disengage the clutch.

5.9.2 Analysis of clutch release fork travel

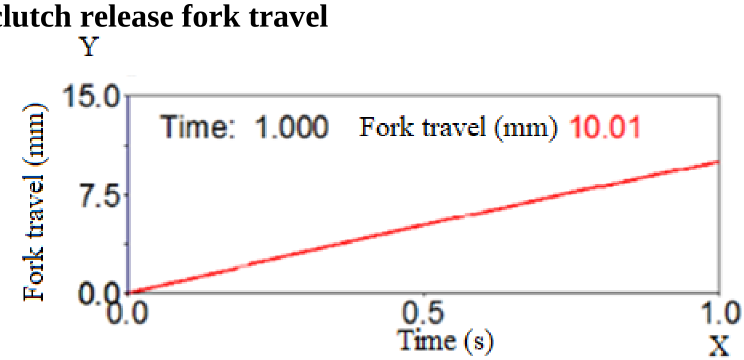

Fig. 5.21 Travel of clutch release fork

Travel of fork is 10.01 mm when solenoid pulls the clutch release fork required 10.01 mm travel for disengage the clutch drive mechanism as shown in fig. 5.21.

5.9.3 Degree of rotation for pedal

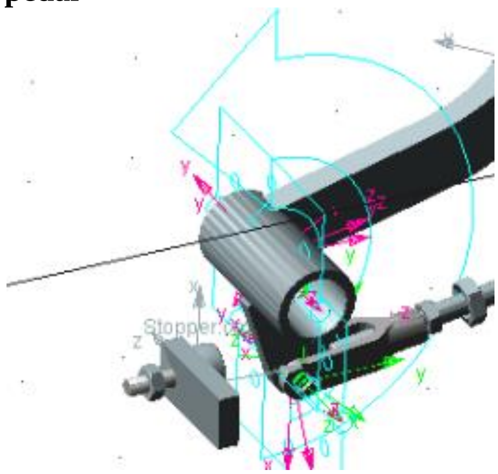

Fig. 5.22 Angular rotation degree of lever

In this fig. 5.22 represent the angular moment of clutch pedal.

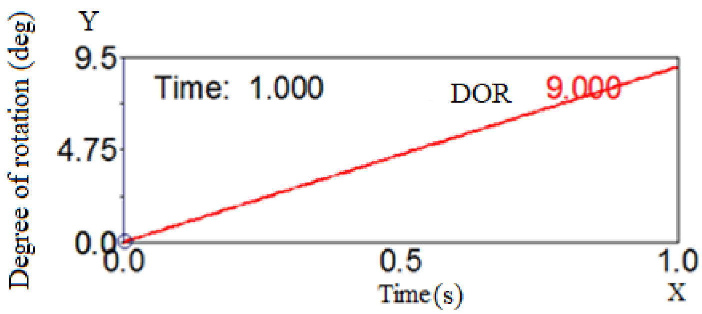

Fig. 5.23 Angular rotation of clutch pedal

Rotation of the clutch pedal is 9 degree for travel the clutch release fork to desired position as represented in fig. 5.22 and 5.23.

5.9.4 Torque required for clutch release fork

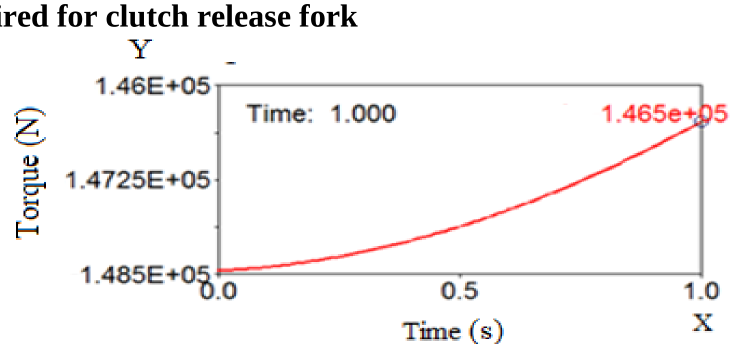

Fig. 5.24 Torque analysis of fork

In this analysis the effort required is more and there is need of high capacity solenoid. The cost of solenoid also increases. New design linkage is proposed for clutch release fork. In new design, there is decrease in effort more than 70% as compared to previous model.

CHAPTER- 6

DESIGN- 4 Reduction of pedal effort using 'v'- shape linkage

6.1 Design-4 of clutch release fork linkages with solenoid

Fig. 6.1 Reference model of 'V' shape link

Slider-crank mechanism, arrangement of mechanical parts designed to convert straight-line motion to rotary motion as shown in fig. 6.1

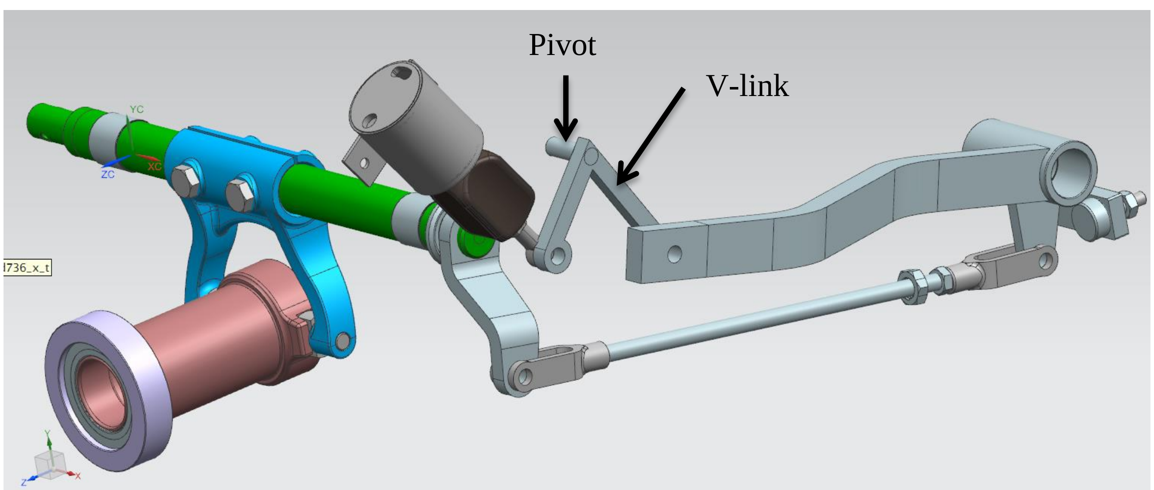

Fig. 6.2 CAD model of new design 'V' type linkages for solenoid and connecting link

This model represent is based on the concept of increase in the leverage ratio with same applied effort. As a result solenoid requires less effort for actuation. In this model 'V' link move around the fixed pivot point. The pivot point transfers the linear motion to the clutch release fork to engaging or disengaging the clutch drive mechanism and solenoid is fixed with the help of bolts of the chassis of the tractor. Solenoid actuator pulls the 'V' link on axial direction of solenoid.

Pivot point helps the solenoid to transfer the motion to the clutch release fork. CAD model of the new design – 4 is represented in fig. 6.2 and 6.3.

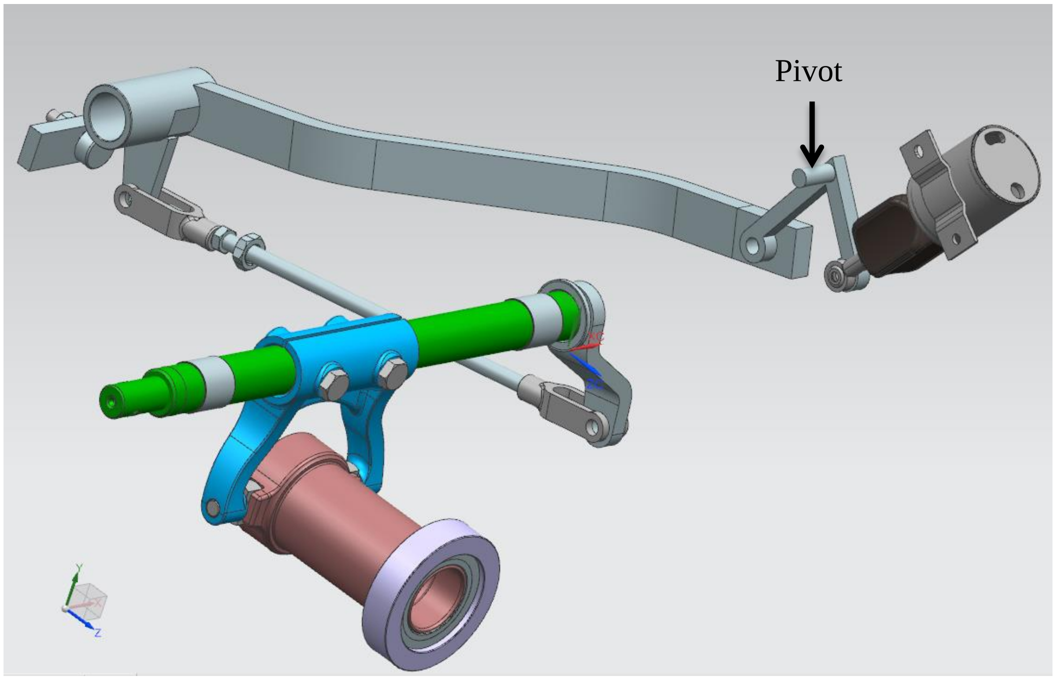

Fig. 6.3 Front view of ‘V’ type linkages

6.2 Feasibility study of ‘V’ type linkage mechanism

In the design of ‘V’ link to engage or disengage the clutch mechanism drive, one side of ‘V’ link is to connect with solenoid and other side is to connect with fork link. Pivot point is fixed, and link rotates relative to pivot point. End of the link connected with clutch release fork, which is not able to move downward in order to engage or disengage the clutch. In this model the link is not able to move linearly with solenoid. With this constraint situation, solenoid fails to provide proper travel towards the clutch release fork. Due to this restricted actuation, release fork did not make contact with clutch plate and there is no engagement/disengagement. Hence, this model is not considerable as per the requirements of clutch model to engage or disengage mechanism drive. This arise the need of a new design of linkage model for clutch release fork.

6.3 New design of linkages

This model is inspired by hand-pump handle (fig. 6.4) and works similar to hand-pump handle working to pull the underground water on the surface. This model also works in the similar fashion to pull the clutch release fork link and linearly move the clutch release fork to engage or disengage the clutch drive mechanism.

Fig. 6.4 Hand pump handle

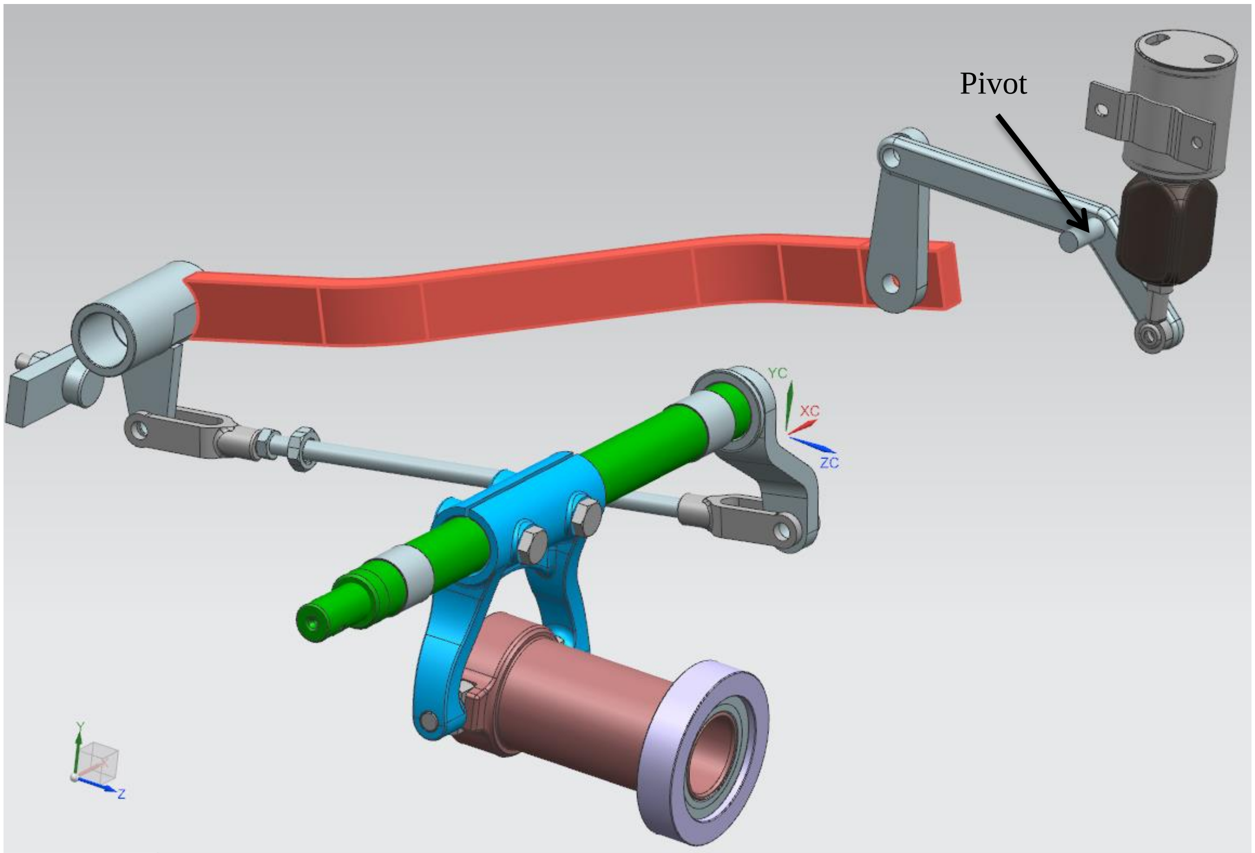

Fig. 6.5 CAD model of new design linkages for solenoid

As shown in model (fig. 6.5), solenoid pulls the connected link with respect to pivot point, which is fixed to the chassis with two bolts. This whole linkage mechanism is placed under 3 point fender (metal cover used as foot stand platform for driver).

As shown in fig. 6.5, there is a four bar mechanism which is used to pull upward the solenoid with the help of four links and joints. There are four points denoted as joint A, B, C and D, which connect the links. Joint A is a rotatory joint, which is the most important joint in this mechanism. Joint A is also known as solenoid pull joint. It is used to pull the solenoid upward with the help of link between the joints A and B.

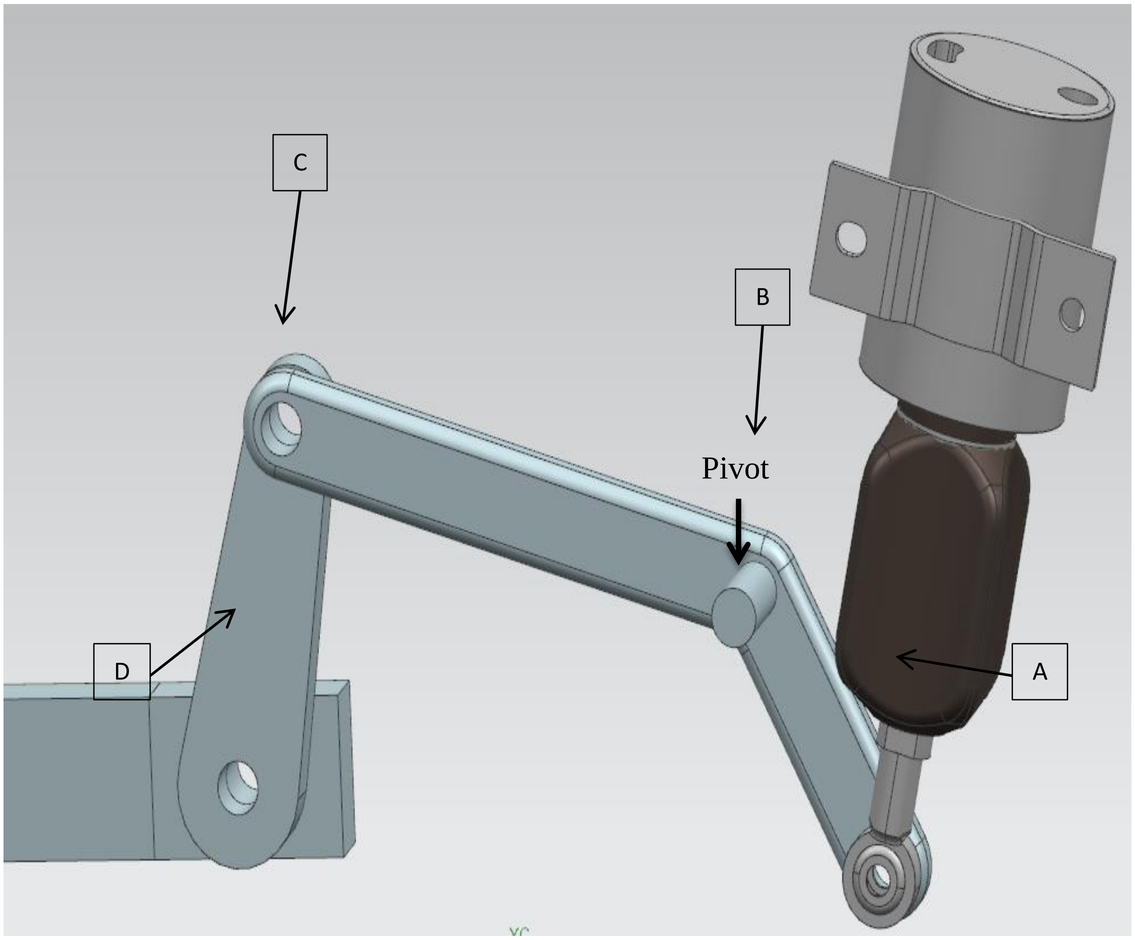

Fig. 6.6 Main feature view of solenoid and connecting link

This link possesses oscillatory connection with other links about joint B acting as a pivot point. The joint C is used to pull this link with the help of rotatory link between joint C and D. The purpose of this mechanism is to convert rotatory motion to translatory. Solenoid is attached with the link A to press the link CD. All the joints are rotary pairs.

6.4 Simulation of new design linkages mechanism

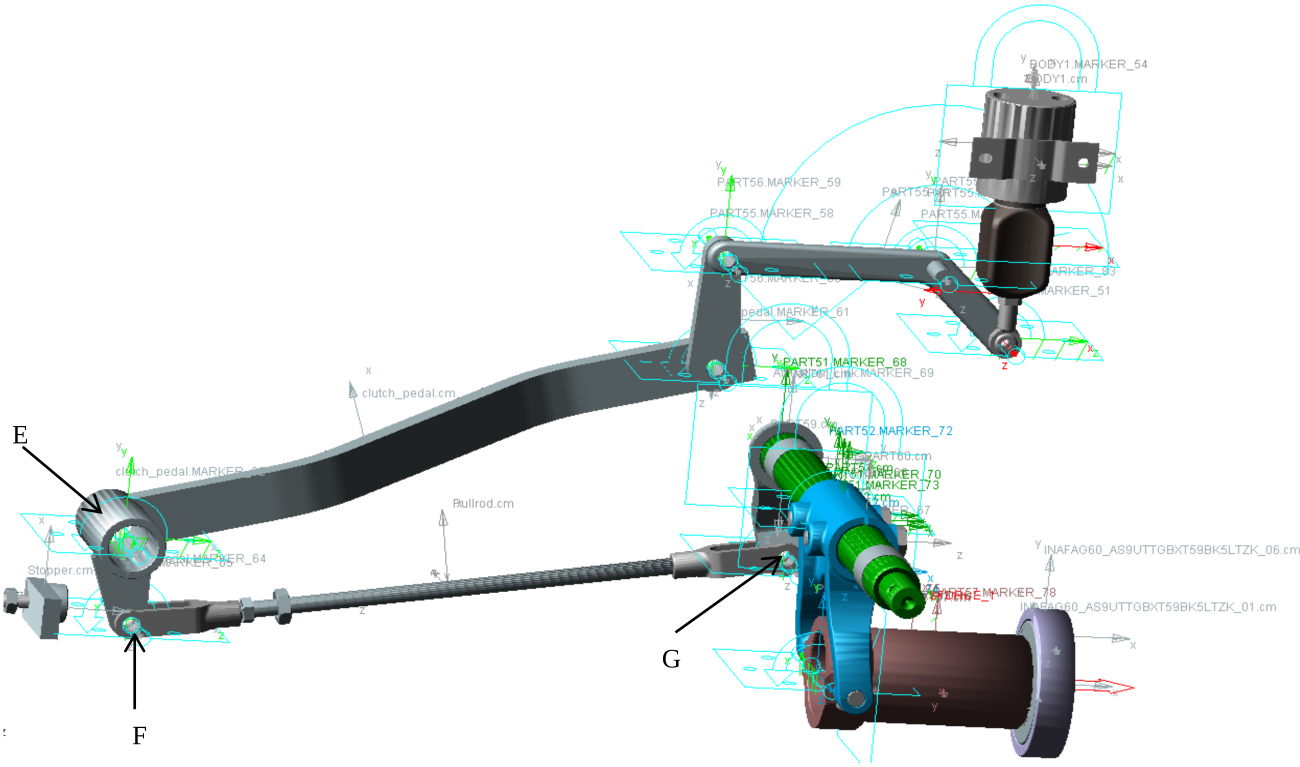

Fig. 6.7 Simulated model of clutch release fork

Solenoid is connected point ‘A’ through a bolt which is fixed. Point ‘A’ is free to have a relative motion with pivot point ‘B’. Point ‘B’ is connected to point ‘C’ which can move both linearly and also have rotation in it. Same motion is observed on point ‘D’. Point ‘E’ produces motion and is responsible for backward motion of point ‘F’. There is also present a stopper against ‘F’ which arrests any further motion. Point ‘G’ will rotate clutch release fork in backward and forward direction in order to engage and disengage clutch drive mechanism.

6.4.1 Travel of clutch release fork

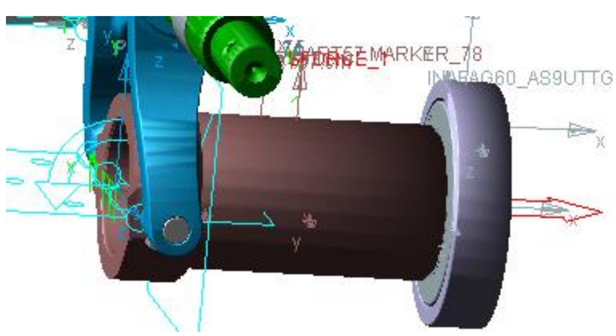

Fig. 6.8 Travel of clutch release fork

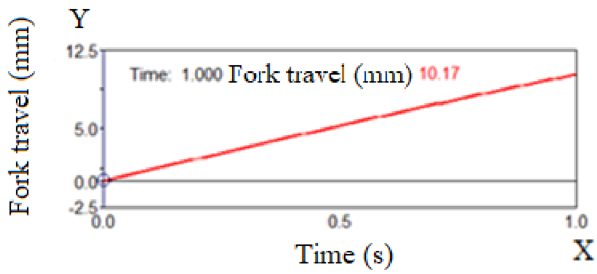

Fig. 6.9 Travel of clutch release fork

It is analyzed from the above graph that on application of solenoid, fork travels 10.17 mm in 1.0 second. The graph is linear in nature which shows no abrupt or sudden jerk movement happened during actuation. Solenoid helps to make clutch engage and disengage mechanism effortless.

6.4.2 Travel analysis of solenoid

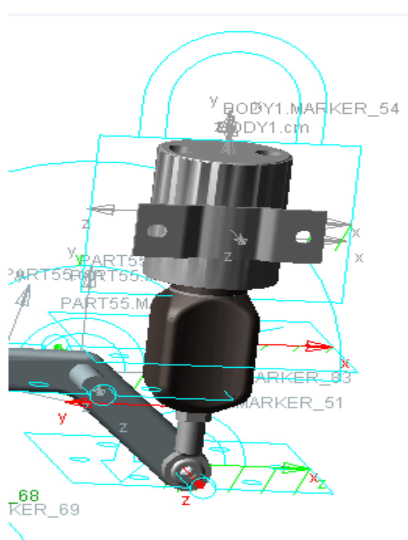

Fig. 6.10 Travel of solenoid

Solenoid is locked in position to tractor chassis with the help of two bolts. Movement of solenoid will be in upward and downward (Y) direction i.e. parallel to the axis of solenoid. Motion of point ‘A’ is through a ball joint which accommodates linear as well as rotary motion requires at this joint.

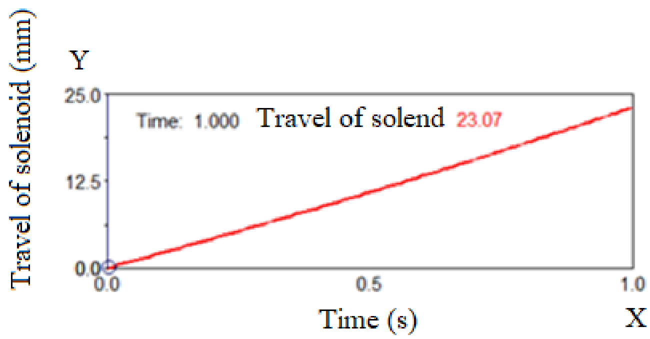

Fig. 6.11 Travel of solenoid

Analysis of above graph (fig. 6.11) shows that solenoid travels 23.07 mm in 1 second. Again it is observed that graph is linear in nature and movement of solenoid is free of any sudden jerk or abrupt motion.

6.4.3 Angular degree of rotation for pedal

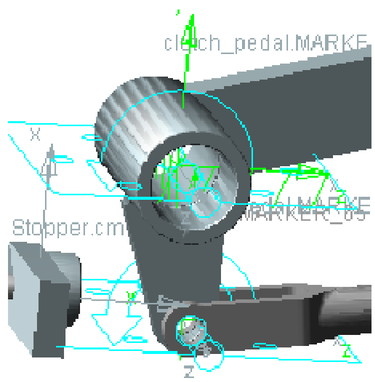

Fig. 6.12 Angular degree of rotation

Shown in fig. 6.12 define the position of angular rotation for clutch pedal and clutch release fork link. This link is providing the rotation as well as linear motion to clutch release fork.

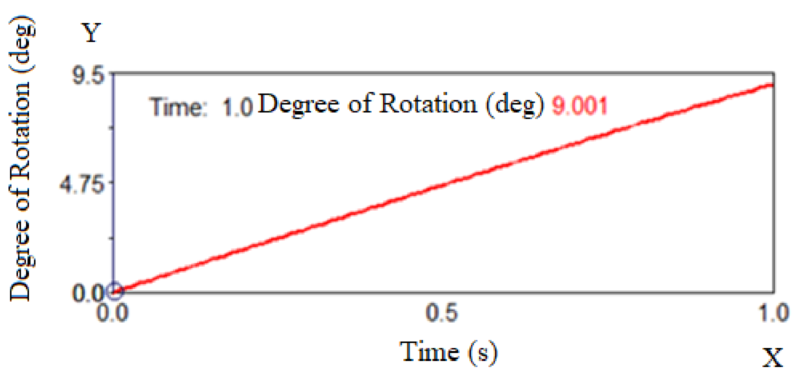

Fig. 6.13 Angular degree of rotation

Analyzing the graph shown in fig. 6.13, it is observed that for every 9.001 degree of rotation, it takes 1.0 second and this motion provides 10.0 mm linear motion to clutch release fork to engage or disengage clutch drive mechanism.

6.4.4 Effort analysis of solenoid

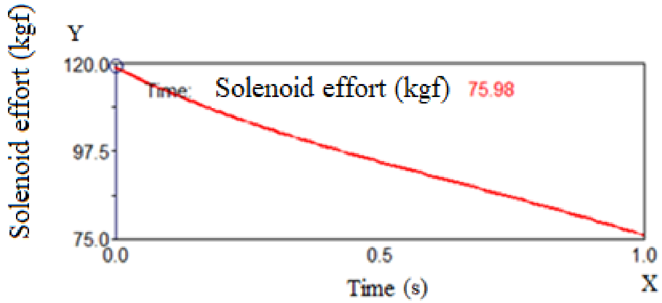

Fig. 6.14 Effort of solenoid

In this model the effort required is high but this design work properly to engage or disengage the clutch drive mechanism. This design requires 75kgf to engage or disengage the clutch derive mechanism.

6.5 Final design of linkages for clutch

Another new design of the linkage is shown in fig. 6.15 to further reduce the effort required by solenoid.

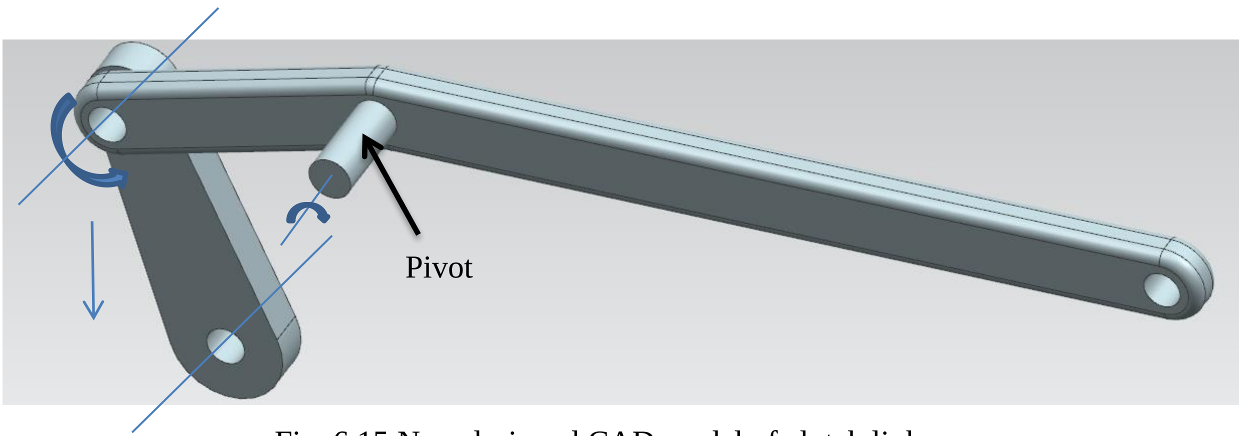

Fig. 6.15 New designed CAD model of clutch linkages

After critically examine the results of previous model, it was found that solenoid effort can be further reduced by changing the pivot point 'B', which is now moved farther from point 'A' and towards point ‘C’. This change in distance creates a new fulcrum at point ‘B’ and effort required to engage and disengage clutch is further reduced.

6.5.1 Dimensions of new design linkages

The dimensions modified for the improved design are represented in fig. 6.16

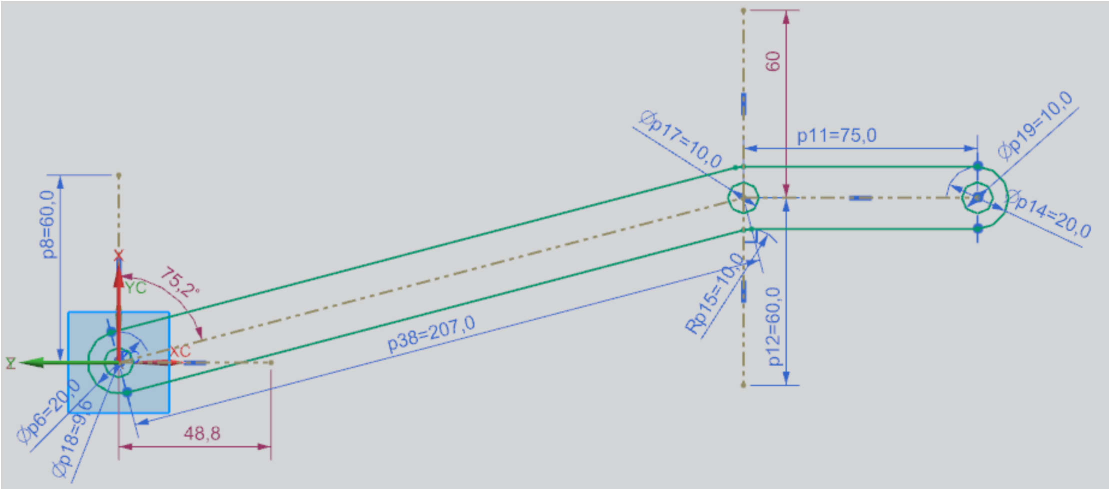

Fig. 6.16 Dimensions of linkages model

Length between point ‘A’ and ‘B’ is 207.0 mm

Length between point ‘B’ and ‘C’ is 75.0 mm

Diameter of point ‘A’ ‘B’ ‘C’ is 10.0 mm

6.6 CAD model of new design for clutch linkages

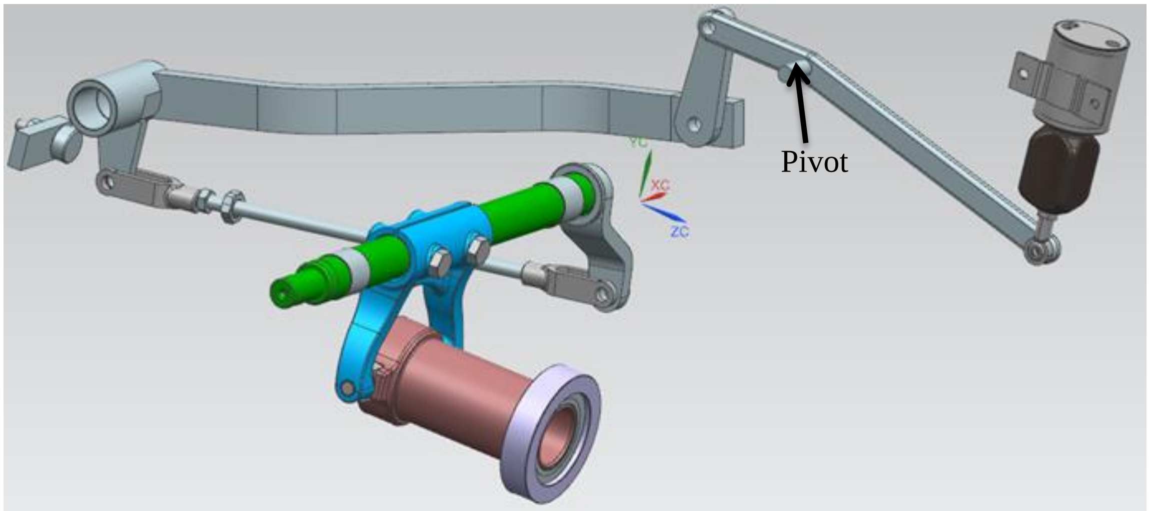

Fig. 6.17 CAD model of clutch release fork

The final CAD model of electric clutch mechanism is shown in fig 6.17. Analysis for the mechanism was performed on ADAMS software, as performed for the previous designs. Solenoid is connected to point ‘A’ through a bolt which is fixed. Point ‘A’ is free to have a relative motion with pivot point ‘B’. Pivot point ‘B’ which is now moved closer in new design to point ‘C’ is connected which can move both linearly and also have rotation in it. Same motion is observed on point ‘D’. Point ‘E’ produces motion and is responsible for backward motion of point ‘F’. There is also present a stopper against ‘F’ which arrests any further motion. Point ‘G’ will rotate clutch release fork in backward and forward direction in order to engage and disengage clutch drive mechanism.

6.7 ADAMS simulated model of clutch release fork with solenoid are

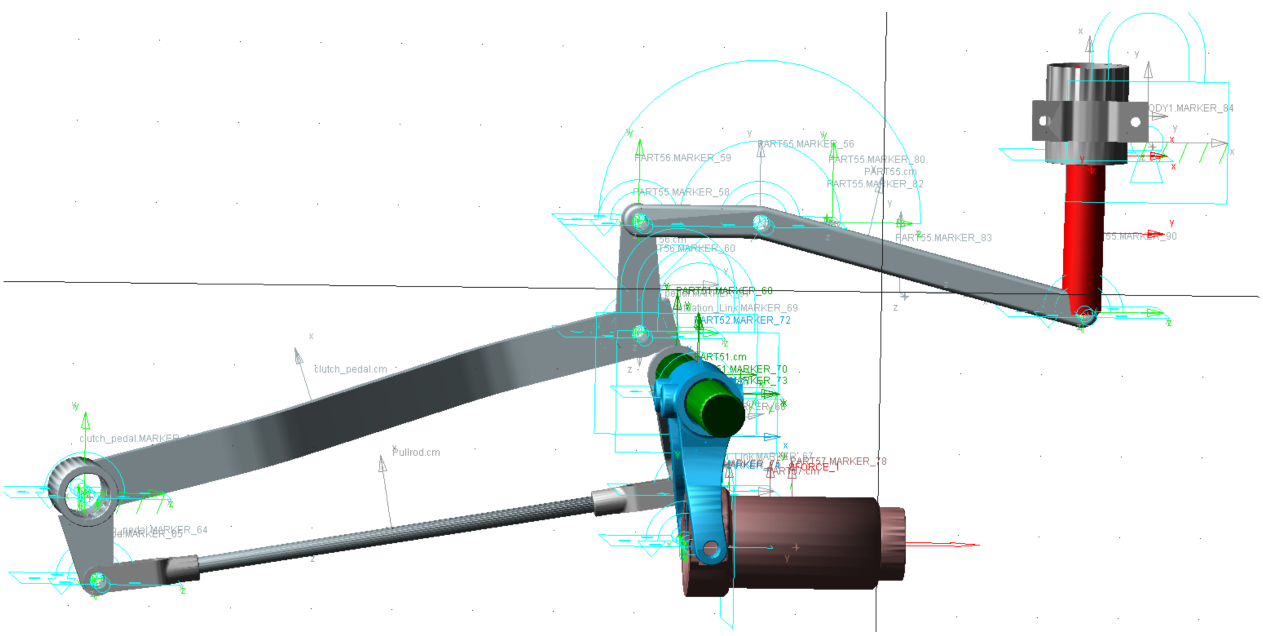

Fig. 6.18 ADAMS simulated model of clutch release fork

By using, ADAMS simulation software, it is observed that solenoid effort required is very less as compared to older model of clutch release fork. The graph below shows that the effort required to engage clutch by the help of solenoid has decreased the effort as in this new design the fulcrum pivot point ‘B was moved towards point ‘C’. This is the final optimized design of this research work.

6.7.1 Angular degree of rotation for pedal

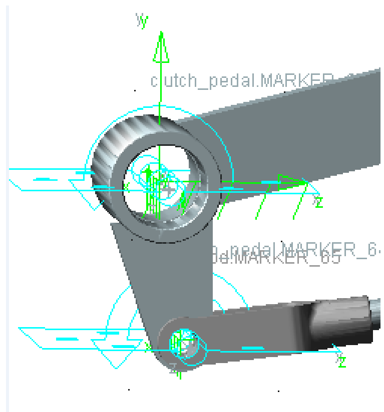

Fig. 6.19 Angular position for connecting link

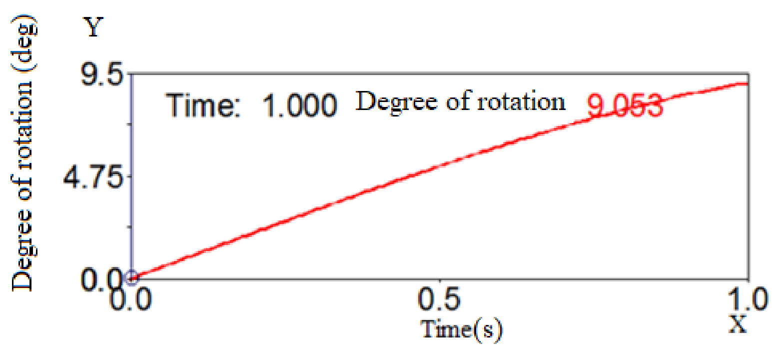

Fig. 6.20 Angular degree of rotation for pedal

Degree of rotation is 9.053 degree for 1.0 second time at point 'E'.

6.7.2 Effort analysis of solenoid

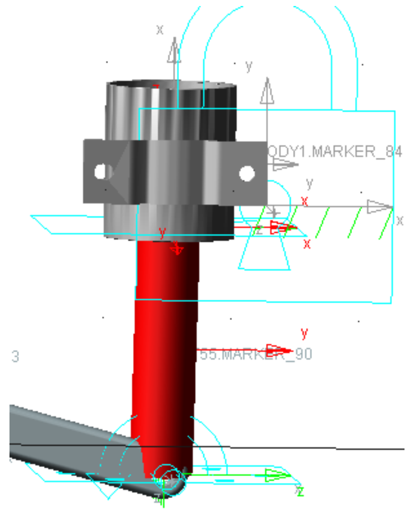

Fig. 6.21 Effort position for solenoid

Solenoid is locked in position to the tractor chassis with the help of two bolts. Movement of solenoid will be in upward and downward (Y direction), parallel to the solenoid. Motion of point 'A' is through a ball joint which accommodates linear as well as rotary motion requires at this joint.

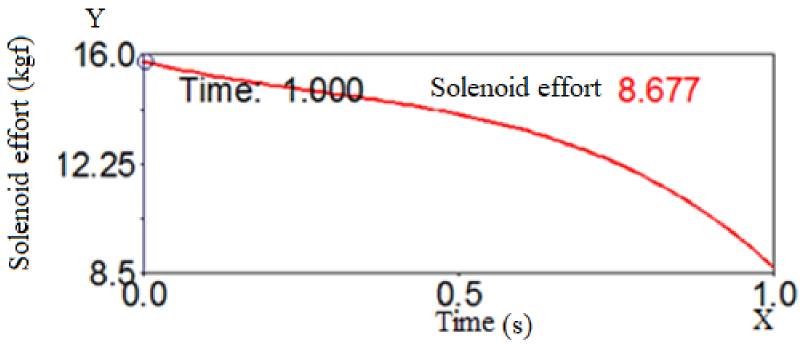

Fig. 6.22 Efforts of solenoid

In this model, there is significant decrease in the solenoid effort, which is now 8.677 kgf. This effort is feasible as per the requirements of the actual model and this model eliminates effort of human leg. The clutch can be engaged or disengaged with the help of a button provided on the gear lever.

CHAPTER- 7

Results and discussion

7.1 Comparisons of all designs

All the models were analyzed under similar boundary condition using ADAMS simulation software. It calculates travel and efforts value of clutch release fork as well as solenoid.

Comparisons of all design is presented below:

Initial investigation presented the comparison of existing clutch mechanism with a solenoid actuated mechanism i.e. Design-1.

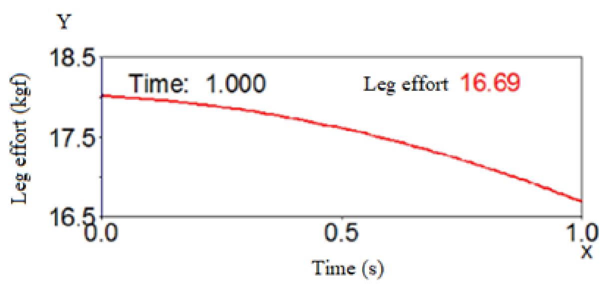

Fig. 7.1 Leg effort on clutch pedal for existing

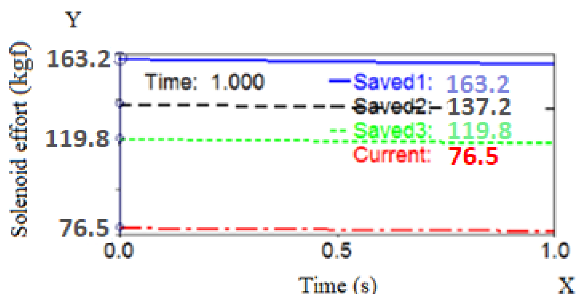

Fig. 7.2 Solenoid effort for clutch operation in Design-1

Effort applied by leg to engage or disengage the clutch drive mechanism for existing design is shown in fig. 7.1. In this model 16.69 kgf is required to press clutch pedal. Whereas, in Design-1 the effort required is more as compare to existing model but in Design-1 and there is no need of human effort to engage or disengage the clutch drive mechanism as shown in fig. 7.1 & 7.2 respectively. In this Design-1, only solenoid provides effort to the clutch release fork to engage or disengage the clutch drive mechanism. But a solenoid of small size cannot provide very high pulling effort. So, here is need to optimize the design of links and their pivot points to decrease the effort of solenoid.

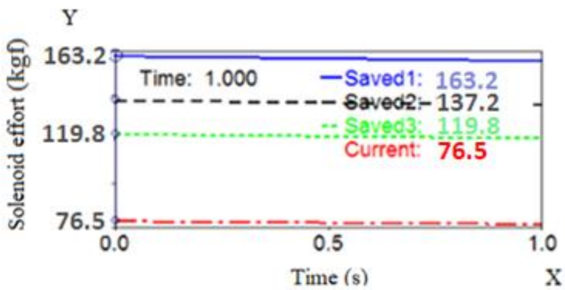

Fig. 7.3 Solenoid effort for Design-1

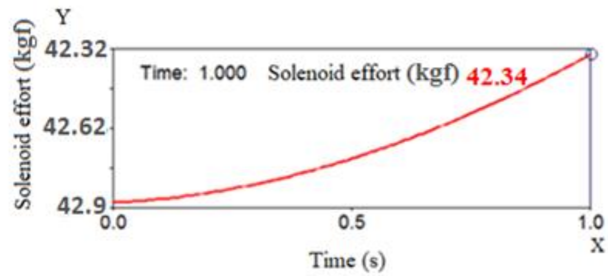

Fig. 7.4 Solenoid effort for Design-2

Both Design-1 and Design-2 were analyzed with the help of solenoid as actuator. Difference between Design-1 and Design-2 is that effort required to engage clutch drive mechanism in Desig-2 is less as compared to Design-1, as represented in fig. 7.3 and 7.4. In Design-2, there is requirement of 42 kgf solenoid effort for clutch operation. In Design-2, the leverage ratio is increases to get the low effort for solenoid. As compare to Design-1, it is considerable to go for further design changes for clutch drive mechanism. But there is requirement of bigger solenoid to engage the clutch drive, which will increase its weight, cost as well as high operating current. So there was scope to optimize the design through link mechanism.

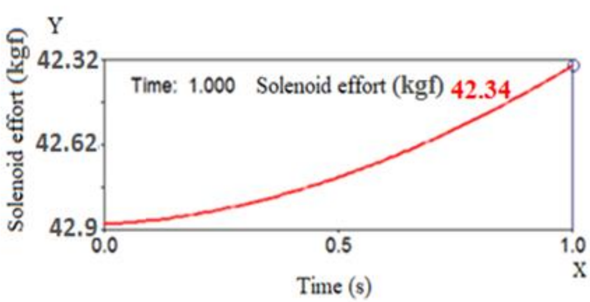

Fig. 7.5 Solenoid effort for Design-2

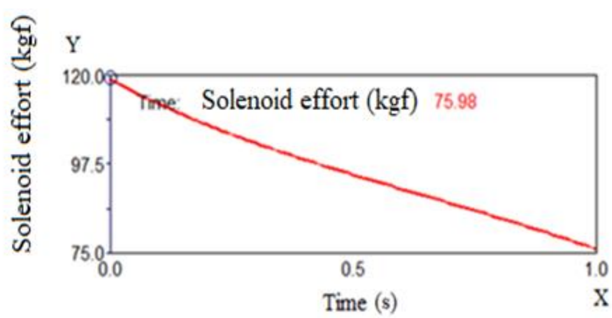

Fig. 7.6 Solenoid effort for Design-3

In Design-3, analysis of new design of linkage of clutch assembly is performed as shown in fig. 7.5 & 7.6. In this design, crank mechanism is used to convert the linear motion into the rotatory motion for clutch release fork to engage or disengage the clutch drive mechanism. But Design-3 effort of solenoid increases to 75 kgf. Again, there is need to optimization the design of linkage to decrease the effort of solenoid. New linkage for solenoid actuation in model Design-4 is analyze.

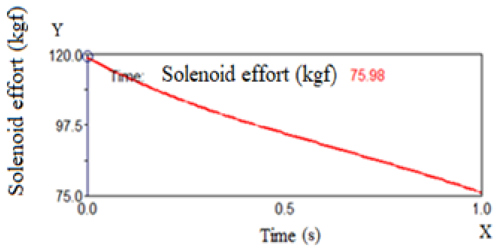

Fig. 7.7 Solenoid effort for Design-3

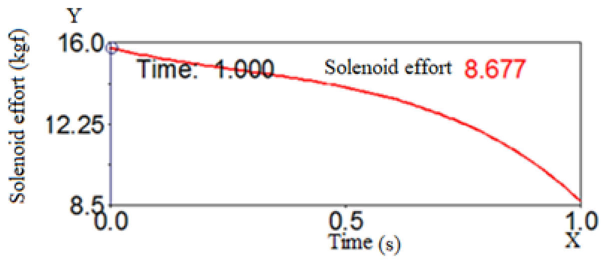

Fig. 7.8 Solenoid effort for Design-4

For Design-3 and 4, analysis was done and compared through fig. 7.7 and 7.8. For Design-4, the effort of solenoid decreases to maximum value of 8.67 kgf. In this model (Design-4), the cost of solenoid is less due to its small size sufficient to provide less required effort. So Design-4 is the final model for the manual transmission of clutch but clutch powered by solenoid. In this model there no need of human leg effort to engage or disengage the clutch drive mechanism. Solenoid is activated with the help of a switch to provide required effort to the clutch release fork to engage or disengage the clutch derive mechanism.

CHAPTER- 8

Conclusions and scope for future work

8.1 Conclusions

On the basis of the present research work, the following conclusions were observed:

1. The effort of the clutch is optimized and it is more responsive for vehicle drive system.
2. This study presented an automated actuation mechanism for the clutch pedal with the use of solenoid as an actuator.
3. Proposed Design-4 helps to eliminate the customer complaints of muscle fatigue.
4. Solenoid actuation is suitable for dual clutch operation.

CAE can prove an effective tool to reduce time and cost in design estimation process, through the concept of durability estimation process.

8.2 Scope for future work

Further investigations are required to work on the linkage mechanism to make it highly responsive for clutch release fork. There is also need to study the clutch drive system to decrease the effort of solenoid. Different types of actuation system for clutch release fork may also be involved in future research. Solenoid can be further implemented in bigger engines used for marine and power plant operations.

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CHAPTER- 1 INTRODUCTION A clutch is an essential part of the drive train components used to transfer torque in different types of machinery. These days, designs of vehicles are largely affected by the need of better comfort of driver. Pedal design is important aspect related to the driving comfort. High clutch pedal effort is a frequent customer complaint as this leads to high fatigue of operator and lesser productivity. Most of the drivers are generally facing problems with knee pain due to high pedal effort. Now day"s latest technologies like turbocharging, wet clutch etc. are incorporated in the drivetrain system which increases engine power but it will also increase the clamping load of the clutch. Increase in clamping load of the clutch tends to increase in clutch pedal effort. Holding bracket Fork supporting rod Connecting wire Clutch pedal lever Kill switch Supporting bracket Running board Spring Fig.1.1 CAD Model of Clutch pedal mechanism [1] 1 Increasing engine power and customer requirements for light clutch, put lot of design challenge on the designers to make it easy in operation and minimum cost of production. In the past various materials have been used like asbestos for disc friction clutch. Typically, an organic resin with copper wire facing or a ceramic material is used in modern day clutches. Generally in heavy applications like racing and heavyweight hauling shipping, ceramic material are used, though the tougher ceramic material adds into the plate wear of flywheel and pressure plate wear. In "wet" clutches composites paper material are very